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AN ANNOTATED BIBLIOGRAPHY ON TACTICAL MAP DISPLAY SYMBOLOGY

John K. Schmidt

August 1989
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U. S. ARMY HUMAN ENGINEERING LABORATORY

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An annotated bibliography on tactical military symbology is provided with corresponding documentation to enhance its use as a reference. The present work is an effort to bring together a rather disparate literature base connected with the portrayal of tactical information on anything from a conventional paper map to an advanced digital map. In addition, pertinent research references concerning specific information encoding techniques are included. Each of the 210 citations presented from the literature contain reference information and an abstract or summary. All listings are indexed by author and subject.

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AN ANNOTATED BIBLIOGRAPHY ON TACTICAL MAP DISPLAY SYMBOLOGY

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August 1989

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AN ANNOTATED BIBLIOGRAPHY ON TACTICAL MAP DISPLAY SYMBOLOGY

BACKGROUND

Tactical map display symbology can be described as graphic images that represent targets of military significance and contain encoded strategic information. Historically, this type of symbology has been depicted on paper maps to convey such things as friendly and enemy positions along with unit size and capability. Initially, the development of electronic sensing devices and displays enabled the depiction of point indicators on grid screens to denote the presence of targets on screens. Later, increased graphic capability permitted the presentation of symbolic images that contained encoded information. Today, the advances made in visual display and computer technology have made the presentation of tactical symbols on digital map backgrounds possible. In addition, the incorporation of information provided from modern sensor and transmission systems has added the capability of providing tactical information in real time.

The unfortunate lack of standardization in developing military systems that use tactical symbology has proliferated many schemes for encoding battlefield information which at times are incongruous with one another. This situation has been cited as a possible limitation to the widespread use of digital map displays to provide situational awareness. In addition, the projected fast pace and increased lethality of the modern battlefield will not only entail the accurate detection and perception of symbology but also the recognition and comprehension of larger amounts of information as quickly as possible. Recognizing the increased importance of symbolic information, it appears the "engineering" of symbols to optimize their processing would be desired.

In order to determine the current status of tactical symbology and associated information techniques in relation to their ability to be effectively processed, a literature review was conducted. As a by-product of this investigation, it was determined that the compilation of the various literature sources would be useful to anyone with specific inquiries about the current holdings on the subject and might identify some research issues that remain to be addressed.

SEARCH PROCESS

The search process for covering the available literature on tactical symbology and related encoding techniques entailed the use of several sources. Specifically, books, scientific journals, technical reports, and conference proceedings were combed via computer inquiries of on-line literature data bases, hand library searches, cross-referencing, and direct contact with symbology researchers to identify appropriate items to be included.

Computer Inquiries

Searches were conducted using key words associated with the tactical symbology literature. Key words used are listed in Table 1. The DIALOG System was used to access the National Technical Information Service (NTIS) holdings.

Table 1

Key Words

SYMBOLOGY with	
	Display
	Map
	Military
	Radar
	Sonar
	Tactical
INFORMATION with	
	Battlefield
	Coding
	Encoding
	Situational
	Tactical
DISPLAYS with	
	Battlefield
	Map
	Military
	Situational
	Tactical

Hand Searches

Manual extractions of sources were made to supplement the computerized searches. One important reason for conducting this operation is that much of the literature from technical conferences is not listed on automated literature data bases and that scientific journal articles may not reflect the operational terminology that is typically used. Reference lists from articles obtained from the computer and hand searches were also cross-referenced. The following sources were reviewed:

<u>Ergonomics</u>

<u>Human Factors</u>

Proceedings of the Human Factors Society Annual Meetings

Journal of Applied Psychology

Journal of Experimental Psychology

Memory and Cognition

Perceptual and Motor Skills

Perception and Psychophysics

Proceedings of the Biannual Symposiums on Aviation Psychology

Psychological Bulletin

Direct Contact

Researchers, who are published or cited frequently in pertinent literature, were contacted, and copies of their recent bibliographies were solicited.

SELECTION CRITERIA

The large number of documents identified through the various search processes made it necessary to establish criteria for limiting the number of references to be included. Generally, the topic had to be directly related to tactical symbology or the encoding of information in symbols; the population and application made had to fall within the realm of human factors research; and the reference had to exist in print.

INDEXING PROCEDURE

Citations are listed alphabetically and are assigned a distinct identification number (001-210). Two indexes using these identification numbers were constructed. The first is a complete listing of all authors, and the second is by subject and subtopical area. It is hoped that the indexes will increase the use of this document.

ANNOTATED BIBLIOGRAPHY

001 Abbott, T. S., Moen, G. C., Person, L. H., Jr., Keyser, G. L., Jr., Yenni, K. R., & Garren, J. F., Jr. (1980). Flight investigation of cockpit-displayed traffic information utilizing coded symbology in an advanced operational environment (NASA TP-1684/AVRADCOM TR 80-B-4). Washington, DC: National Aeronautics and Space Administration/St. Louis, MO: U.S. Army Aviation Research and Development Command. (DTIC No. AD-A087 663)

Studies initiated during the early 1970's provided initial exploration of traffic-situation display concepts in a simulation environment. During the present study, the traffic symbology was encoded to provide additional information concerning the traffic, which was displayed on the pilots' electronic horizontal situation indicators (EHSI). The purpose of this study, which was conducted using a research airplane representing an advanced operational environment, was to assess the benefit of coded traffic symbology in a realistic work-load environment. Traffic scenarios, involving both conflict-free and conflict situations, were employed.

Subjective pilot commentary was obtained through the use of a questionnaire and extensive pilot debriefings. These results grouped conveniently under two categories: display factors and task performance. A major item under the display factor category was the problem of display clutter. The primary contributors to clutter were the use of large map-scale factors, the use of traffic data blocks, and the presentation of more than a few airplanes. In terms of task performance, the CDTI was found to provide excellent overall situation awareness. Additionally, the pilots expressed a willingness to utilize lesser spacing than the 2 1/2 nautical mile separation prescribed during these tests.

002 Ainsworth, J. S. (1979). Symbol learning in Navy technical training: An evaluation of strategies and mnemonics (TAEG Report No. 66). Orlando, FL: Training Analysis and Evaluation Group. (DTIC No. AD-A068 041)

This study has two objectives. The first was to evaluate the instructional effectiveness of materials designed in accordance with the algorithm for symbol learning contained in the Interservice Procedures for Instructional System Development (NAVEDTRA 106A). Special emphasis was placed on assessing the usefulness of graphic-type mnemonics (memory aids) recommended by the algorithm. The second objective was to demonstrate the feasibility of producing effective instructional materials using computer-aided authoring routines.

This evaluation was conducted at the Signalman "A" School at the Naval Training Center in Orlando, Florida. The set of symbols selected for the study was the International Morse code. The subjects were 160 Navy and Coast Guard enlisted men. A 2x4x3 repeated measures design was used to determine the differential effects of aptitude, type of instructional material, and amount of study time on the acquisition of Morse code. Four types of instructional material were compared. There were (1) the traditional materials (study guide pages and flash cards), (2) a Guided Practice handbook (137 pages), (3) a Mnemonics Only handbook

(13 pages), and (4) a Guided Practice with Mnemonics handbooks were prepared via the use of computer-aided authoring routines.

003 Allport, D. A. (1971). Parallel encoding within and between elementary stimulus dimensions. Perception & Psychophysics, 10, 104-108.

Human ability to encode simultaneously different dimensions of a visual display was tested, using an "erasure" technique to control the time for which the visual information remained available for processing. Three separate vocabularies of test item were employed, one varying in terms of color and two in terms of form attributes. Simultaneous presentation of color and form stimuli gave evidence of nearly perfect parallel encoding of both types of attribute. Form-form combinations, on the other hand, indicated only partially simultaneous encoding of the primary form dimensions involved. It was suggested that, while primary encoding of different stimulus dimensions is simultaneous, within the same dimension encoding of discrete stimulus elements may occur seriatim.

(From Perception & Psychophysics, 1971, 10, pp. 104-108. Reprinted by permission of Psychonomic Society, Inc.)

004 Alluisi, E. A. (1960). On the use of information measures in studies of form perception. Perceptual and Motor Skills, 11, 195-203. Summary.

Some of the classical generalizations relating to form perception in man have been identified loosely with certain information measures. The connection suggests, for example that the "simplicity" of a shape or pattern is related to the uncertainty of that pattern as a stimulus. Finally, a review of a selected sample of some of the more recent studies of form perception is presented; this review is meant to illustrate the use of information measures in perceptual studies and the influence of an "informational approach" to form perception.

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005 Alluisi, E. A. (Ed.). (1961). Lineal inclination in encoding information symbolically on cathode ray tubes and simulator displays (ASD-TR-61-741). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division. (DTIC No. AD-278 825)

Four experiments are summarized in this report. They constitute a series of investigations aimed at determining how lineal-inclination symbols should be used to encode information optimally on cathode ray tubes and similar displays in future air traffic control and related systems.

An equal-discriminability scale of lineal inclination was constructed and validated in the first two studies; in addition, normative data were collected from a large number of subjects using the four alphabets specifically

recommended. The second two investigations were concerned with (a) the effects of using different readout systems and (b) the effects of displaying the symbols in different visual surrounds.

The report is divided into two sections. Section I is intended primarily for engineers; it contains specifications and recommendations for engineering applications of lineal-inclination symbols. Section II contains the detailed results of the four experiments; it will probably be of principal interest to research psychologists.

006 Alluisi, E. A., & Martin, H. B. (1958). An information analysis of verbal and motor responses to symbolic and conventional Arabic numerals. Journal of Applied Psychology, 42, 79-84.

This experiment was designed to compare the information-handling performance of Ss in making verbal and motor responses to two sets of Arabic numerals--one a set of conventional figures, the other a set of symbolic figures drawn from an eight-element straight-line matrix. The motor (key-pressing) responses to the different stimuli were made by a group of 24 Ss over a period of two days, and by five Ss over a longer period of 12 days. An identical number of different Ss made verbal (number-naming) responses for the same length periods.

When verbal responses were made, the conventional numerals were consistently superior in performance to the symbolic numerals. This was true whether performance was measured in terms of information handling (in bits/sec.), time, or errors. No such clear superiority was evidenced for either set of numerals when motor responses were made.

007 Alluisi, E. A., & Muller, P. F., Jr. (1958). Verbal and motor responses to seven symbolic visual codes: A study in S-R compatibility. Journal of Experimental Psychology, 55, 247-254.

The information-handling performance of 10 Ss was measured with conventional Arabic numerals and six other symbolic visual codes under both motor- (key-pressing) and verbal-response conditions. The six symbolic codes included a set of straight-line symbolic Arabic numerals, three sets of ordered symbols based upon differences in the visual inclination of a line, a set of colors, and a set of ellipses of differing axis ratios. The two response modes were used to lend generality to the results and to extend the study of S-R compatibility effects. Both self- and forced-paced rates of information presentation were used, with the latter being varied from 2 to 6 bits/sec. in unit steps. The major results were as follows:

1. The seven codes fell into three clearly different groups under each response condition: the two numerical codes were superior to the three inclination codes, and these were all superior to the two remaining codes of color and ellipse-axis ratio.

2. Verbal-response performance with the two numerical codes was nearly perfect over the forced-paced rates used here. However, under all other forced-paced

conditions, equivocation increased with increases in the rate of information presentation above the minimum of 2 bits/sec.

3. In self pacing, verbal responses with each code were made with greater accuracy than motor responses, but motor responses were made with greater speed than verbal.

4. Interactions of stimulus codes with response modes were found in both self- and forced-paced performances; these interactions were interpreted as illustrations of S-R compatibility effects.

008 Alluisi, E. A., Muller, P. F., Jr., & Fitts, P. M. (1957). An information analysis of verbal and motor responses in a forced-paced serial task. Journal of Experimental Psychology, 53, 153-158.

The present experiment was designed to determine whether the rate of information transmission in a forced-paced serial task is a function of (a) the rate of stimulus presentation, (b) the uncertainty per stimulus, or (c) the joint effect of these two factors expressed as the rate of information presentation. Arabic numerals were used as stimuli and 10 Ss responded to them with both verbal and motor responses. Within the ranges from 1 to 3 bits/stimulus and 1 to 3 stimuli/sec., the data appear to justify the following conclusions.

1. For a given rate of information presentation an increased rate of information transmission was obtained by an increase in the number of possible alternative stimuli and a corresponding decrease in the rate of stimulus presentation. Significant decrements were also found in the relative information transmission rate with increases in the rate of stimulus presentation, but no significant decrements occurred with increases in the number of alternative stimuli. Thus, in forced-paced tasks it appears that the rate of handling information is not a simple function of the rate of information presentation per se.

2. The differences found between verbal and motor responses to identical stimuli are interpreted as a further instance of variation in S-R compatibility, not as an indication of a general superiority of verbal over motor responses.

3. The results are interpreted as indicating two important interaction effects in forced-paced serial tasks: (a) the interaction of stimulus complexity with stimulus rate, and (b) the interaction of stimulus code with response mode (S-R compatibility effects).

009 Anderson, N. S., & Fitts, P. M. (1958). Amount of information gained during brief exposures of numerals and colors. Journal of Experimental Psychology, 56, 362-369.

In the present experiments the problem of how much S can perceive during the brief exposure of a group of stimulus objects is re-examined from the viewpoint of the relation of amount of information transmitted to information coding and amount of information displayed.

Groups of homogeneous color or shape symbols, or combined color-numeric symbols, were exposed for .1 sec. The information content of the groups of symbols (messages) varied from 9.51 to 25.36 bits per message. The Ss wrote down estimates of all the symbols in each message. Results were analyzed separately for each S in terms of information transmitted.

Performance at first increased and then decreased as information content per message was systematically increased, reaching different maxima for each of the three coding schemes studied. From the present viewpoint, therefore, it is not meaningful to summarize perceptual ability in terms of the number of objects that can be reported following a brief exposure; it can only be said that reporting ability is maximum for messages of some specific level of complexity (information content).

Maximum average information transmitted about color (Exp. II) was 10.44 bits per exposure, with messages that contained four color symbols. Maximum average information transmitted about numerals (Exp. II) was 14.94 bits, with messages that contained six symbols. Maximum information transmitted about the color-numeric symbols was 18.64 bits, with four symbols; this was significantly greater than the information transmitted after exposure of any of the messages comprised of the two simpler alphabets.

In spite of the relative superiority of the color-numeric alphabet, the information gained from viewing groups of these complex symbols for a .1-sec. interval is somewhat less than would be predicted from independent data regarding (a) ability to identify stimulus levels along single coding dimensions on an absolute basis under favorable viewing conditions, and (b) immediate memory ability.

The superiority of the color-numeric symbols, whose use required Ss to report data regarding both figure and background, is consistent with the notion that figure-ground perception is a unitary process; however, this superiority may be due at least in part to more effective use of central vision and/or to more effective recoding of information for immediate memory.

010 Andrews, R. S., Vicino, F. L., & Ringel, S. (1968). Relation of certitude judgments to characteristics of updated symbolic information (Technical Research Note 194). Washington, DC: U.S. Army Behavioral Science Research Laboratory. (DTIC No. AD-831 288)

Technological advancements in military operations and stepped-up need for command tactical decisions consistent with rapid change and succession of events requires maximal effectiveness in the processing and use of military operations information. To this end, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. As part of the requirements for research, a series of studies has been conducted by the COMMAND SYSTEMS Task in which a variety of display variables are systematically investigated in terms of their effects on information assimilation and decision making in a command and control setting. The present study explores the effects of type and number of updating change, amount of information presented, and selected enhancement techniques on confidence and on the relationship of confidence to accuracy of information

assimilation. In the experiment, nine successive pairs of 35mm negative transparencies were viewed by 48 subjects. The first slide of a pair contained 12, 18, or 24 military flag symbols randomly positioned on a map. The second slide was identical to the first except that 2, 4, or 6 symbols had been added, removed, or repositioned. Subjects viewed both slides, then, after removal of the second slide, indicated on a paper print of the first slide all updates they had noted on the second. Performance was measured in terms of accuracy of assimilation (percentage score) and certitude expressed in that accuracy. For analysis, successive integer values of 1 - 8 were assigned to the eight certitude judgment categories ranging from absolutely uncertain at the lower end of the continuum to absolutely certain at the upper end. This experimental procedure was repeated for each of the three type-of-change sequences within a session--single-cue coding, double-cue coding, and hard copy as well as for a no-coding condition. Findings indicate: (1) The more effective the enhancement technique, the higher the certitude-accuracy relationship. With the best enhancement technique (double-cue coding), 64 percent of the certitude variance could be accounted for by accuracy variance; with the poorest (hard copy), only 20 percent. (2) Both over-certitude and under-certitude was evidenced, with over-certitude tending to increase with the less effective enhancement techniques. (3) Increase in either amount of information presented or amount of updating resulted in decline in both mean accuracy and mean certitude, the rate varying widely over the different enhancement techniques and over types of update. (4) Although effects of the main variables on accuracy and certitude were highly similar, the correspondence did not hold for individual performance scores. Findings suggest need to improve agreement between a man's performance in information assimilation and his judgment of that performance. To more adequately determine the nature of the effects of enhancement, certitude should be measured in the same quantitative metric (percent) as accuracy.

011 Arnberger, E. (1974). Problems of an international standardization of a means of communication through cartographic symbols. International Yearbook of Cartography, 14, 19-35.

The paper primarily discusses the difficulties encountered in establishing an international standard for cartographic symbols. Specifically, a differentiation is made between topographic cartography and thematic cartography in that the latter is much more varied in focus than the former, thus making it more problematic to depict. The paper then suggests some practical ways to go about developing a thematic symbology system.

012 Attneave, F. (1957). Physical determinants of the judged complexity of shapes. Journal of Experimental Psychology, 53, 221-227.

Judgments of the complexity of 72 shapes were obtained from 168 Ss. The shapes were constructed by a method in which certain physical characteristics were systematically varied and the remainder randomly determined. About 90% of the variance of ratings was explained by (a) the number of independent turns (angles or curves) in the contour, (b) symmetry (symmetrical shapes were judged more complex than asymmetrical with number of independent turns constant, but less complex with total number of turns constant), and (c) the arithmetic mean of

algebraic differences, in degrees, between successive turns in the contour. Angular and curved shapes were judged about equally complex, though the latter involved additional degrees of freedom (radii of curvature). Also immaterial, within broad limits, was the grain of the matrix from which critical points were chosen to construct the shapes.

013 Attneave, F., & Arnoult, M. D. (1956). The quantitative study of shape and pattern perception. Psychological Bulletin, 53, 452-471.

The article discusses the present state of quantitative study of shape and pattern perception. Generally, due to several difficulties encountered in its study, the field has not progressed very far and an adequate psychophysical framework for its study is needed. The discourse then elaborates on how form perception would lend itself well to psychophysical study. Finally, several kinds of analyses and related measures, which appear appropriate to quantitatively study shape and pattern perception, are presented.

014 Baker, C. A., Morris, D. F., & Steedman, W. C. (1960). Target recognition on complex displays. Human Factors, 2, 51-61.

This study was conducted to determine the speed and accuracy of form recognition as a function of: (1) the amount of distortion between the reference form and the target form, (2) the number of irrelevant forms in the target display, and (3) the stimulus properties of the forms involved. The stimulus forms were generated by filling in, on a statistical basis, some of the cells of a 90,000-cell matrix. The subjects were shown a reference photograph of a target and instructed to locate that target on a display containing numerous other forms. Both criterion measures, viz., search time and errors, increased as as function of: (1) an increase in the number of irrelevant forms on the target display, and (2) an increase in the difference between the resolution of the reference form and that of the target display. A quantitative description of the targets, which can be used to predict relative target difficulty, was developed.

015 Baker, C. H. (1960). Factors affecting radar operator efficiency. Journal of Navigation, 2, 148-163.

This paper briefly reviews some of the research findings with respect to factors which affect the efficiency of radar operation. One of the most important factors in determining whether or not a radar target will be visually detected is the brightness of the radar scope. A simple method is described for setting optimum scope brightness. Visual search habits are discussed and the implications of such habits for the design of radar displays are pointed out. Reference is made to some of the design factors which determine the accuracy with which target range and bearing are reported. It is shown that human monitors

perform less efficiently as a watch progresses and factors which impair or aid their vigilance are described. Finally, a brief account is given of illusions on radar displays.

(From Journal of Navigation, 1960, 2, pp. 148-163. Copyright 1960 by the Cambridge University Press. Reprinted by permission.)

016 Baldwin, R. D., Wright, A. D., & Lehr, D. J. (1962). The relation between radar detection and the observer's concept of a target (RM-HRRO). Fort Bliss, TX: U.S. Army Air Defense Human Research Unit. (DTIC No. AD-288 440)

The results of this study support the hypothesis that under impoverished stimulus conditions radar detection performance is directly related to the dimensional complexity of the observer's concept of a target. The importance of these cognitive components of the radar observer's behavior have not been adequately recognized in typical training programs. Usually, detection training is accomplished employing the demonstration method. At best, mention may be made of the brightness difference between targets and noise. The results of this study also support the Erdmann and Myers hypothesis that the target's form is a critical attribute influencing detection under high noise conditions.

017 Banks, W. P., & Prinzmetal, W. (1976). Configurational effects in visual information processing. Perception & Psychophysics, 19, 361-367.

These experiments show that the perceptual organization of a multielement display affects both the speed and accuracy with which a target letter in it is detected. The first two experiments show that a target is detected more poorly if it is arranged in good form (a perceptual Gestalt) with noise elements than if it is not. This effect is not confounded with target-noise proximity or display size, and it holds for stimuli terminated by the subject's response as well as for stimuli of very brief duration. Increasing the number of noise elements can actually improve performance if the added noise elements increase the degree to which the noise elements form perceptual groups separately from the target. A third experiment tries out a new method for scaling the perceptual structure of an array, and it shows that the main features of the first two experiments can be predicted from the scaled perceptual structure of the arrays they used.

(From Perception & Psychophysics, 1976, 19, pp. 361-367. Reprinted by permission of Psychonomic Society, Inc.)

018 Beller, H. K. (1970). Parallel and serial stages in matching. Journal of Experimental Psychology, 84, 213-219.

Two experiments were performed to test Neisser's two-stage model of recognition as applied to matching. Evidence of parallel processing was obtained in Exp. I, where Ss could respond *same* as quickly to eight identical letters as to two identical letters. Evidence for a succeeding serial stage was obtained in Exp. II. When Ss matched letters of uppercase and lowercase and the number of letters differing in case was increased, response times also increased. Anomalies in the data can be resolved by requiring the first stage of processing to segment stimuli. Since Neisser originally postulated this, the model is not inconsistent with the present data.

019 Berger, C. (1944). Stroke-width, form and horizontal spacing of numerals as determinants of the threshold of recognition. Journal of Applied Psychology, 28, 208-231 & 336-346.

1. A method and procedure is described to investigate the influence of stroke-width of white and black numerals, specific form-factors, distances between the strokes of numerals, distances between two numerals and surroundings upon the threshold of recognition, with a view towards improvement of the recognizability of the numerals. The same method is applied to conditions of night-vision of medium dark-adaptation.

2. A construction is found for 9 numerals, white on black background, luminous during night-conditions, which are optimally recognizable (standard area-42 mm. X 80 mm.) and which at the same time are adjusted to standard in such a way, that each single numeral as well as two and five-number constellations appear or disappear at the same distance from the eye, a distance which is the greatest possible distance for the particular area chosen.

3. During the investigation the following results were registered:

(*a*) Numerals, white on a black background, have an optimal average recognizability, if their stroke-width is 6 mm. on an area 42 mm. X 80 mm. Numerals, black on a white background, have an optimal average recognizability, if their stroke-width is 10 mm. on an equal area. The proportion of this stroke-width to the inner horizontal distances of the numbers is in the first case about 1 : 5, in the second about 1 : 2.2. The white numerals are under these conditions, singly, about 8.2 per cent more recognizable than the optimally constructed black numerals for the same area.

(*b*) Investigating many detailed characteristics of form, it was found that the angle under which two horizontal lines are connected (or two vertical lines) has a particular importance for the recognition of a numeral. The recognizability is best with angles which cut the adjacent parts of the area into two equal halves. A vertical or horizontal connection is least recognizable.

(*c*) A five-number group requires about 10 per cent more space between the numerals than 2 numbers alone, even though the space between the two numerals already has been adjusted to standard.

(*d*) A white frame around white numerals improves their legibility only if at a certain distance from the top and base of the numerals, and only if its width is equal to the stroke-width of the numerals. Then the improvement is about 9 per cent.

(*e*) Under ordinary night-conditions (medium dark adaptation) very slender, luminous numerals at threshold brightness are about 17.8 per cent more recognizable than optimally constructed white numerals with reflected light.

(*f*) The relations of these results to previous theoretical work are discussed, and it is pointed out that they not only corroborate theoretical conclusions concerning structural as well as functional concepts of the human eye, particularly its fovea, but may also lead to interrelations between purely physiological and certain esthetic aspects of human vision.

020 Bersh, P., Moses, F. L., & Malsano, R. E. (1978). Investigation of the strength of association between graphic symbology and military information (Technical Report 324). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A064 260)

Each of 114 enlisted men ranked battlefield information categories (e.g., Unit Level, Danger, and Firepower) in the order of their strength of association with different sets of symbols, with members of each set varying in a single characteristic. In related tasks, these persons were asked to rank order military branch or duty designations and tactical function terms by how well they were suggested by both geometrical symbols and miscellaneous "stick" symbols. A second group of 137 enlisted men had the reverse task of ranking symbols against one another for their strength of association with military concepts. The participants, from the 3rd Infantry (The Old Guard), had only limited prior exposure to military symbology. Results were categorized as high, medium, minimal, and insignificant associations, based on the statistical significance of differences among ranks and on the degree of reflexive associations between symbols and concepts.

Results suggest that "natural" associations can be found between graphic codes or symbols and military concepts. About half of the primary matches between tactical concepts and symbols fell into the high- and moderate-association categories. High associations are those that show little or no ambiguity about which symbol and concept belong together. The three high-association categories were (1) the currently used link between numerosity (number of lines) and Unit Level (e.g., company, division), (2) the link of color with Danger, and (3) the link of a square with Service Support. All moderate associations had at least some ambiguity. A noteworthy cluster of four symbols was associated with the Maneuver Unit concept. These same four symbols were also associated with 8 out of 10 other military branch or duty designations. The other half of the association results, including the currently used associations of an ellipse for Armor, an X for Infantry, and of color for Friend/Enemy, fell into the minimal- or insignificant-association categories.

021 Bishop, H. P., & Crook, M. H. (1961). Absolute identification of color for targets presented against white and colored backgrounds (WADC-TR-60-611). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-266 403)

The number of stimulus colors which can be absolutely identified by normal subjects when viewed against various colored backgrounds was investigated.

Additive mixtures of light passed through narrow-band and Illuminant-C filters were projected onto a viewing screen by a device which permitted independent control of target and background characteristics. The stimulus parameters of hue, luminance, purity, target size, and target shape were varied, and the effects of such factors as training and the presence of a distracting task were studied. With target luminance above background luminance, about nine hues plus white, three luminance levels, and two purity levels, are estimated to be useful for operational coding, if no more than about 30 of the possible combinations are included in the set. Under optimal working conditions and with protracted training, the maximum size of an identifiable set is estimated to be about 60. Reduction of target luminance below the luminance of a colored background was found to make identification very difficult. No significant effect of target shape was found.

022 Bitterman, M. E., & Krauskopf, J. (1953). Some determinants of the threshold for visual form (WADC-TR-53-331). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-23 337)

A diffusion model for visual form perception was derived from the Kohler-Wallach theory of figural after-effects. Implications of the model were tested in experiments designed to measure foveal form and brightness thresholds (for luminous figures briefly exposed in a dark room) in terms of intensity of illumination. Form and brightness thresholds were found to vary inversely with exposure-time and with area. Form thresholds varied also with the magnitude of critical detail. Data on the pre-threshold appearance of selected forms were related to results obtained with a physical diffusion model. Preliminary findings on variations in critical flicker frequency with form and on changes in size at threshold levels of illumination also were reported.

023 Bjork, E. L., & Murray, J. T. (1977). On the nature of input channels in visual processing. Psychological Review, 84, 472-484.

The research reported herein was designed to assess whether the presence of noise elements in a visual display affects the detection of target letters at the perceptual or feature extraction level of processing, as well as at the decision level, and more specifically, whether (a) input or processing channels operate in an independent or interactive fashion and (b) how the spatial relation between signal and noise items affects detection performance. In order to distinguish among current theories proposed to account for the influence of noise items on visual processing, a forced-choice detection task was modified to incorporate a cueing procedure, which permitted the independent variation of signal-noise similarity, confusability, and proximity. The results provide evidence for feature-specific inhibition at the perceptual level, and a theory is proposed that assumes hierarchically organized, limited-capacity feature detectors and feature-specific inhibitory channels.

024 Blair, W. C. (1957). An evaluation of three proposed sets of radar symbols (Technical Memorandum 8-57). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-301 064)

This study evaluated three proposed sets of symbols for use on radar scopes to identify targets. Two techniques were used; one used a tachistoscope and yielded visual recognition thresholds through successive discriminations, and the second used a simulated radar scope and yielded time and error identification scores through simultaneous discriminations. The results indicated that performance differences as a function of a set of symbols was significant, that the three sets could be ranked, that performance decreased as number and proportion of symbols increased, and that time scores decreased as density per area was increased. Such variables as color and non-geometric symbols need to be evaluated, as well as other possible parameters. It is recommended that further studies be undertaken to determine an optimum set of symbols.

025 Bloomfield, J. R. (1972). Visual search in complex fields: Size differences between target disc and surrounding discs. Human Factors, 14, 139-148.

An adaptable technique for performing search experiments, enabling extensive studies to be undertaken with well-practiced observers, is described. In each trial a single target disc was presented. Cumulative distributions of the times taken to locate 6 solid disc targets of varying size in a display containing 99 larger standard discs arranged in a regular fashion, and 3 disc targets in a display of 107 larger discs arranged irregularly, are presented. Three practiced observers were used with each display. Sixty readings per observer, per target, per display were obtained. It is suggested that for the targets most different in size from the background discs, the distributions of times to locate are largely dependent on response time factors; and for the targets closest in size the distributions are largely dependent on search factors. Some support is lent to theoretical work that suggests search times are exponentially distributed. The shortest time required to locate a particular target is used as an estimate of response time. Response times are found to be inversely proportional to both the difference between the log of the target and nontarget disc diameters, and to the difference between the diameters. An amendment, taking response time into account, is suggested for exponential search equations.

026 Boer, L. C., & Keuss, P. J. G. (1982). Global precedence as a postperceptual effect: An analysis of speed-accuracy tradeoff functions. Perception & Psychophysics, 31, 358-366.

Two experiments examined the speed-accuracy tradeoff for stimuli used by Martin (1979), some of which have a Stroop-like conflict between the relevant (to-be-judged) and the irrelevant aspect. Speed of transmitting information about a local aspect was significantly reduced when the irrelevant global aspect

conflicted with the relevant local aspect, while speed of transmitting information about the global aspect was *not* affected when the irrelevant local aspect conflicted with the global aspect. This result, when extrapolated to the accuracy level of an ordinary reaction-time task, fitted very well the reaction-time predictions of the global precedence model proposed by Navon (1977). However, other results were incongruent with the fundamental assumption of that model: that global features are accumulated with temporal priority over local features. The finding that, independently of speed, information transmission of the global aspect started later when the irrelevant local aspect was conflicting, corroborates Miller's (1981a) conclusion that global and local features are available with a similar time course. Global precedence is therefore a postperceptual effect; absence of interaction with S-R compatibility suggested that it operated before the response selection stage. The term *global dominance* may be preferred, because it avoids the implication of prior availability for the global aspect. Furthermore, the possibility of whether Stroop conflict should be considered a necessary condition for global dominance is discussed.

(From Perception & Psychophysics, 1982, 31, pp. 358-366. Reprinted by permission of Psychonomic Society, Inc.)

027 Bowen, H. M., Andreassi, J. L., Truax, S., & Orlansky, J. (1960). Optimum symbols for radar displays. Human Factors, 2, 28-33.

Experiments were conducted to determine: 1) sets of geometric symbols which can be discriminated from each other and recognized with high accuracy under a variety of display conditions, especially those involving degradation of the image in ways similar to those that occur on radar displays, and 2) the size and strokewidth to height ratio desirable for symbols to be used on complex displays.

The recommended symbols are illustrated in the report; symbol height should be 1/2 inch or more and the strokewidth should be 1/8 to 1/10 of the height.

Suggestions for combining auxiliary symbols with primary symbols are given.

(From Human Factors, 1960, 2, pp. 28-33. Copyright 1960 by the Human Factors Society, Inc. Reprinted by permission.)

028 Boynton, R. M. (1957). Recognition of critical targets among irrelevant forms. In J. W. Wulfeck & J. H. Taylor (Eds.), Form discrimination as related to military problems (pp. 175-184). Washington, DC: National Research Council.

The presentation covered research performed by the author and his colleagues to determine the influence of the following four variables on recognition behavior: 1) number of figures in the array; 2) distance between an observer and an array; 3) exposure time to the array; and 4) contrast of the array figures against its background. Generally, an increased number of figures as well as distance from an array will decrease correct recognition performance; whereas, an increase in

exposure time as well as contrast to and in an array respectively will increase correct recognition performance.

029 Brainard, R. W., Campbell, R. J., & Elkin, E. H. (1961). Design and interpretability of road signs. Journal of Applied Psychology, 45, 130-136.

The results of the study can be summarized as follows:

1. Interpretability of the European signs was partly a function of the method by which interpretability was examined. The mean interpretability score from Phase I was considerably lower than for Phase II, although the correlation between the two methods was significant.

2. The European signs were moderately well interpreted on first presentation; after one exposure to the correct meaning, interpretability approached 100%.

3. The easily interpreted European signs were generally pictorial representations of the sign meanings or were counterparts of American road signs. The signs which were difficult to interpret generally used abstract, unfamiliar symbols or included ambiguous cues.

4. Stereotypes for some road signs exist. The general characteristics found in the stereotypes were the same as those in the easily interpreted European signs.

5. Interpretability is enhanced if signs are stereotype-based. However, signs based on stereotypes of only moderate strength (30-40%) will not always be highly interpretable.

6. A small number of the European road signs could be efficaciously used in the United States, without necessitating prior instruction as to their meaning. The majority of the signs, however, could not be used without a minimal degree of familiarization.

030 Brandes, D. (1976). The present state of perceptual research in cartography. Cartographic Journal, 13, 172-176.

This paper discusses the current state of perceptual research concerning cartographic symbols. Initial discussion treats the theories and reasons behind the present popularity of perceptual studies in cartography. It is followed by a summary of the printed materials on this topic appearing in several prominent English language cartographic publications. A person who is newly entering the area of perceptual research in cartography may use this paper as a quick source for obtaining background in the area and thereby save valuable time from sifting through individual sources for information regarding what has already been done. Additional convenience is provided for the reader by the grouping of references according to the subject matter which they concern.

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031 Briggs, G. E., & Blaha, J. (1969). Memory retrieval and central comparison times in information processing. Journal of Experimental Psychology, 79, 395-402.

Memory load and display load were varied orthogonally in a simple information-reduction task which required *S* to respond either "yes" or "no" that a visual display does or does not contain an item previously memorized. Twelve *S*s were given extended (12 days) practice. Reaction time was a linear function of memory load, and the slope constants of that relationship were a linear function of display load for positive responses and a power function of display load for negative responses. The fitted equations provided indexes of memory retrieval time and central comparison time separately. These times decreased systematically with practice. It was concluded that throughout *S* performed an exhaustive serial comparison process with display rechecking prior to a negative response.

032 Briggs, G. E., & Johnsen, A. M. (1972). On the nature of central processing in choice reactions. Memory & Cognition, 1, 91-100.

A procedure for generating values of central processing uncertainty was developed from positive response data in a varied-set version of the Sternberg choice reaction task. This is a logical extension of a previously validated procedure for data from a fixed-set version of the same task. Both procedures provide information on the additive components of reaction time. It was concluded that S resolves more uncertainty in the varied-set than in the fixed-set situation. It was concluded also that S performs a rechecking operation prior to emitting a negative response, and this rechecking apparently involves less information than does the original testing for stimulus classification. This, in turn, suggests that rechecking is a self-terminating process with regard to display information. The results also imply that stimulus classification is partially serial and partially parallel, so a hybrid model may be appropriate for this task.

(From Memory & Cognition, 1972, 1, pp. 91-100. Reprinted by permission of Psychonomic Society, Inc.)

033 Briggs, G. E., Thomason, S. C., & Hagman, J. D. (1978). Stimulus classification strategies in an information reduction task. Journal of Experimental Psychology: General, 107, 159-186.

Three experiments, each using a slightly modified form of the Sternberg information reduction task, were performed. In the Sternberg task, the subject classifies several stimuli into two sets, one having been memorized previously by the subject and the other consisting of all stimuli not in the memorized set.

The data of Experiment 1 indicated that the subjects may have been changing their information processing strategy to make the classifications as a function of the probability of occurrence of the items in the memorized set. The changes seem to be in the number and order of tests of different hypotheses concerning the classification of the test stimulus.

Based on the data from Experiment 1, there seem to be two basic hypothesis tests: (a) that the test stimulus belongs to the memorized set and (b) that the test stimulus belongs to the nonmemorized set. When the subjective probability of occurrence of a memorized set item is very much less than .5 (in this case, it was .25), a test for membership in the nonmemorized set occurs first, followed by a test for membership in the memorized set. Hypothesis testing in this case is exhaustive. When the probability of memorized set item occurrence is .5 or greater, a test for membership in the memorized set occurs first, followed by a test for membership in the nonmemorized set. In the case of a very large probability (e.g., .75) of memorized set item occurrence, a third test, one for membership in the memorized set, may follow the second. In these cases, hypothesis testing is self-terminating between hypothesis tests.

Experiment 2 was primarily a test of several predictions concerning the distributional characteristics of the observed reaction times. The obtained data conformed to the predictions, supporting the hypothesis of changing strategy.

Experiment 3 was a test of predictions concerning the effects of different constraints on the time allowed for processing the stimulus upon the number of correct responses and upon the direction and magnitude of response bias. Again, the obtained data conformed to the predictions, further supporting the hypothesis that changes in stimulus classification strategies in the Sternberg information reduction task occur as a function of the probability of occurrence of items for the memorized set.

034 Brooks, R. (1965). Search time and color coding. Psychonomic Science, 2, 281-282.

In an attempt to determine the effect of color coding on search time, six groups of 10 S's each were asked to respond to 10 different displays containing 60 symbols, some of which were color coded. Comparisons among conditions revealed that there was a significant difference in search times only between a "color" and a "no color" condition.

(From Psychonomic Science, 1965, 2, pp. 281-282. Reprinted by permission of Psychonomic Society, Inc.)

035 Bruck, L. A., & Hill, P. W. (1982). Tactical situation displays and figurative symbology (Master's thesis). Monterey, CA: Naval Postgraduate School. (DTIC No. AD-A115 737)

This thesis investigates the utility of figurative symbology for tactical situation displays. The purpose was to determine if more descriptive symbology--figurative symbology or use of more lifelike images to represent targets--would enhance evaluation of a tactical situation display, i.e., enable the user to more rapidly assimilate and evaluate a tactical situation display. Basis for comparison was the Navy Tactical Display System (NTDS). Specifically,

experiments used in our research included comparisons of monochromatic NTDS, color NTDS, and color figurative symbologies.

The analysis of the data obtained from the experiments suggests color symbology is significantly better than monochromatic symbology and figurative is better than NTDS symbology. Specifically, color figurative (green/red) was determined to be best, followed in order by, color figurative (blue/orange), color NTDS, then monochromatic NTDS.

036 Cahill, M. -C. (1975). Interpretability of graphic symbols as a function of context and experience factors. Journal of Applied Psychology, 60, 376-380.

Ten of the graphic symbols designed by Henry Dreyfuss Associates for Deere and Company farm and industrial machinery were tested for ease of interpretation in context and in isolation. Subjects were mechanical engineering students (*N* = 30) who differed in their extent of familiarity with such equipment. As hypothesized, the symbols were more often correctly identified in context and by subjects with relevant prior experience. Symbols maintained the same relative order of difficulty under both context and no-context conditions, a difficulty which ranged from 100% correct responses to only a few correct responses. It was concluded that empirical validation of effectiveness is a necessary, although often neglected, step in the symbol development process.

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037 Cahill, M. -C. (1976). Design features of graphic symbols varying in interpretability. Perceptual and Motor Skills, 42, 647-653. Summary.

Ten of the graphic symbols designed by Henry Dreyfuss Associates for Deere and Company farm and industrial machinery were presented to 30 mechanical engineering majors for interpretation in context and in isolation. Approximately half of the 15 subjects in each condition had specific prior experience with the type of machinery for which the symbols were intended. Individual symbols were differentially affected by the two factors of context and experience, but relative ease of recognition among the symbols as a set persisted unchanged. Specific design features of the symbols were examined in an attempt to account for their variation in interpretability. While pictorial and "grammatical" aspects were involved, the more successful symbols were distinguished primarily by being representations of commonplace rather than technological objects and actions

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038 Cahill, M. -C., & Carter, R. C., Jr. (1976). Color code size for searching displays of different density. Human Factors, 18, 273-280.

Twenty observers searched for three-digit numbers on displays ranging in density from 10 to 50 items coded in one through ten colors. Search times increased linearly with density and showed a curvilinear relation to number of colors used. An initial drop in search times as the first few colors were added to an uncoded display was followed by a rise in search times as still more colors were used. Minimal search times at different display densities were associated with different code sizes. Search times increased as more colors were added to the code, even when the number of items per color category was constant. The detrimental effect on search times of larger code sizes is interpreted as a camouflage of the color contour of the target's class by the multiple color boundaries in the heterogeneous background.

039 Cannon, M. W., Jr. (1977). A spatial frequency analysis model for predicting human performance at visual pattern matching tasks (AMRL-TR-77-43). Wright-Patterson Air Force Base, OH: Aerospace Medical Research Laboratory. (DTIC No. AD-A041 649)

A model for simulating human performance in visual pattern matching tasks is presented. The model is based on evidence of spatial frequency processing in the visual system, and on the hypothesis that shape recognition is determined only by the low spatial frequency harmonics of the image. Two psychophysical pattern matching experiments are described that demonstrate a clear functional relationship between the "similarity" of two patterns as judged by human observers and the Euclidean distance between spatially filtered Fourier transforms of the patterns.

040 Carter, R. J. (1981). An investigation of geometric radar shapes for stereotyping (Technical Report 570). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A131 120)

This investigation sought to determine whether any of the symbols which are currently being used or are proposed for usage in future air defense systems are stereotyped with the meanings hostile, friendly, and unknown.

Each of the 100 male service members sorted 60 shapes into four categories, namely friend, hostile, unknown, and other depending upon what each shape connoted. The personnel also rank ordered the shapes which had been sorted into the first three categories. Chi square statistics were used to analyze the data.

Shapes were identified which are stereotyped with the three meanings. The 5-Pointed Star, Heart, and Flag were associated with the friend meaning. The Swastika and Question Mark were associated with the hostile and unknown meanings respectively.

The results of this experiment will be utilized in future research which will be aimed at deriving a standard symbology for application to radar assisted air defense systems.

041 Carter, R. J. (1981). Standardization of geometric radar symbology: 3-symbol set testing in a static cathode ray tube mode. Proceedings of the Human Factors Society 25th Annual Meeting, pp. 145-148.

Two experiments oriented towards identifying symbols and sets of symbols which can be quickly and easily discriminated were conducted. Radar console operators performed a search task on a cathode ray tube which approximated a console screen at a moderate saturation level. Analyses of variance and Chi square statistics were used to analyze the reaction time and error data. Symbols and sets of symbols were found which exhibited the two attributes.

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042 Casperson, R. C. (1950). The visual discrimination of geometric forms. Journal of Experimental Psychology, 40, 668-681.

Discrimination data were obtained for 30 solid geometric figures consisting of five variations in the construction of each of six basic forms: an ellipse, diamond, triangle, rectangle, cross and star. Percent of correct reports, corrected for response frequency, was plotted as a function of area, maximum dimension and perimeter. The effectiveness of each variable in predicting discriminability for the different forms and figures was determined by comparing the variance remaining between figures having equal threshold amounts of each of the three variables. That variable which produced the least variance between functions was considered the best predictor of discriminability.

043 Chan, P. Y., Swanson, L. M., & Whisnant, D. L. (1980). Investigation of new techniques for the presentation of operations/intelligence information: Vols. I & II (RADC-TR-80-10). Griffiss Air Force Base, NY: Rome Air Development Center. (DTIC No. AD-B045 601)

The problem of presenting operations and intelligence information to Air Force decisionmakers in clear and understandable terms has grown in magnitude as the complexity of tactical and strategic electronic systems has increased. This is especially true within the intelligence community where significant increases in the availability of data have occurred through development of automated sensor systems. The ensuing development of new management, analysis, and reporting systems to control and filter the collected information for use by the analyst, commander and his staff requires new techniques to better present the large amount of operations/intelligence information.

Both interest in and methods of presenting operations/intelligence data to a variety of users are common to the military command and intelligence community. The more common presentation techniques utilized in existing management, analysis, and reporting systems include alphanumeric lists, tables, service common-message formats, and graphics using classic military symbols on both color and monochromatic displays. There are some inherent limitations associated with the use of these more common presentation techniques. One problem area concerns the volume or mass of data that is reviewed. Using traditional display techniques to present data from sophisticated sensor systems, decisionmakers cannot efficiently review, correlate, and assess the significance of the large amount of information elements available to them. Somewhat related is the problem of the amount of time that can be allocated to the review of this information. As the sophistication of battlefield systems increases, both in the air and on the ground, the tactical situation becomes more dynamic. To win the battle, the commander must make his tactical decisions more rapidly, which requires accurate and timely information that is well presented. As problem areas were identified, it became apparent that new techniques have to be found for display of the most critical information elements. At the same time, a way has to be developed which exploits the synergistic effect produced by combining these separate information elements into the most comprehensive operational presentation for use by staff decisionmakers.

One way of defining the problem which the investigation of new presentation techniques addresses is as follows: How to display operations/intelligence information to staff decisionmakers to optimize their perception of that information as it relates to the operational mission and its status. Key elements of this problem statement that require investigation are: operations/intelligence information requirements for staff decisionmakers, display technology, display techniques and human factors. These elements directly affect the effectiveness of information presentation. This report describes the result of investigation of new techniques for presentation of operations/intelligence information. The investigation encompasses a study of the key elements identified in the problem of information display.

A description of display technologies is given in section 2. The technologies examined include direct view CRT's, flat panel displays, large screen projection displays, and three-dimensional displays.

Human factors in display systems design is discussed in Section 3. Two aspects of human factors which affect the perception of presented information are the physical configuration design of the display system, and the man-machine dialog considerations.

A survey of existing display techniques is described in Section 4. The predominant mode of information presentation in computer-driven display systems is the use of visual displays. Visual displays include both graphic and alphanumeric displays. Graphic display techniques are grouped into six categories and described.

Operations and intelligence information requirements for Air Force staff decisionmakers are discussed in Section 5. These are grouped into the presentation requirement categories of ground activity, airfields/bases, airborne, SAM/AAA defenses, mission results, topographics and weather. They serve as a baseline for investigation of new display techniques.

A list of new display techniques to augment current information display systems is given in Section 6. New display techniques are described and a tradeoff analysis is performed to determine their applicability. Tradeoff criteria are selected from the areas of hardware, timeliness, software, applicability, human factors, risk and cost. These criteria make use of results learned in the investigation of display technology, human factors, display techniques, and information requirements for decision makers.

A paper implementation which demonstrates how the new display technique candidates can be used for presentation of operations/intelligence information is described in Section 7. These techniques were selected from the list of new display techniques described in Section 6, based on the result of tradeoff analysis.

Finally, conclusions and recommendations resulting from the investigation efforts are described in Section 8. General guidelines are given whenever possible and meaningful in the areas of selection of display technology, human factors design, and display techniques. Concerning the proposed new display techniques, those selected for paper implementation have been shown to be applicable to the presentation of operations/intelligence information, and entirely compatible with computer implementation.

044 Checkosky, S. F., & Whitlock, D. (1973). Effects of pattern goodness on recognition time in a memory search task. Journal of Experimental Psychology, 100, 341-348.

Four factors were varied in a memory search task and their effects on mean reaction time (RT) were evaluated. The factors were (*a*) pattern goodness of test stimuli and memory set items as defined by reflection-rotation equivalence set size (after a 1963 study by Garner and Clement); (*b*) discriminability (perceptual clarity) of the test stimuli; (*c*) the similarity of the test stimuli which require a *no* response to the memory set items (similarity). The joint effect of pattern goodness and stimulus discriminability was additive. This was interpreted as evidence that the time to form an internal representation of the test stimulus is not influenced by the goodness of the stimulus. At the same time the effect of pattern goodness on RT interacted with memory load. This was interpreted as evidence that the time to generate a visual representation of the memory set items is influenced by the goodness of these items. A significant Pattern Goodness X Similarity interaction was also obtained. This was interpreted in terms of differences in the metric for similarity between good and bad patterns. Further, such an interaction suggests that pattern goodness influences the time to compare the test stimulus with the memory set items.

045 Christ, R. E. (1975). Review and analysis of color coding research for visual displays. <u>Human Factors</u>, <u>17</u>, 542-570.

The experimental literature on the effects of color on visual search and identification performance was reviewed. Forty-two studies published between 1952 and 1973 were located that gave results which could be used to determine the effectiveness of color codes relative to various types of achromatic codes. Quantitative analyses of these results indicated that color may be a very effective performance factor under some conditions, but that it can be detrimental under others. Tentative conclusions about the nature of these conditions were derived from the results. A guide for design decisions and indication of knowledge gaps are also provided.

046 Christner, C. A., & Ray, H. W. (1961). An evaluation of the effect of selected combinations of target and background coding on map-reading performance--experiment V. <u>Human Factors</u>, <u>3</u>, 131-146.

The objective of this study was to determine the relative effectiveness of selected target-background coding combinations. Three target codes were: color, number, and enclosed shape. Five types of background were: all white, solid gray, five shades of gray, five pastel hues, and five different patterns. These target-background coding combinations were evaluated under eight different complexity conditions and five different operator tasks. The major findings in this study were: (1) no significant differences were found in background coding, (2) numeral coding is superior for the "identifying" task, and (3) color coding is superior for the "locating" and "counting" tasks.

047 Ciccone, D. S., Samet, M. G., & Channon, J. B. (1979). <u>A framework for the development of improved tactical symbology</u> (Technical Report 403). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A076 017)

In order to develop a comprehensive framework for defining symbology issues, an analysis was performed to identify task-based information requirements. The analysis was based on four basic task dimensions consisting of (1) a user category--i.e., command group, combat support staff, and service support staff; (2) a task category--i.e., assessment, planning, and tactical communications; (3) a military operations category--i.e., offense, defense retrograde, and special operations; and (4) an information category--i.e., enemy situation, and terrain/weather.

The task-based information analysis was demonstrated to be an effective means for eliciting from experienced tacticians many of the "questions" important to battlefield command and control operations. These questions were categorized into three types: (1) those amenable to expression via current symbology; (2) information deficiencies--i.e., tactical questions which current symbology has failed to answer; and (3) information imperatives--i.e., new questions which will require new types of symbolization.

The products of this analysis will contribute to a methodology which will aid in the development of new or modified tactical symbols that portray the status of the battlefield more completely and understandably.

048 Cohen, J. (1955). Binocular disparity as a coding dimension for pictorial instrument and radar displays (WADC-TR-55-393). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-093 633)

Two experiments were done in order to determine the increments of binocular disparity angle which would result in equal discriminability of absolute depth judgments. On the basis of the results, we can specify the discrete amounts of binocular disparity to present to the operators of three dimensional cathode ray tube displays; or conversely, we can state the relative accuracy with which operators would be able to make depth discriminations over the range of binocular disparities between the upper and the lower limits of fusion.

The first experiment employed nineteen subjects who recorded depth judgments on a continuous scale, and the second employed twenty subjects who recorded their depth judgments in eleven discrete categories. Twenty-two pairs of test slides with four disparate targets on each slide were presented to the subjects in the same stereoscope in both studies. The responses were scaled by the method of the R scale transformation; this involves normalizing the data, and separating the response categories by equal standard deviation distances. The computed R scale increments were found to be proportional to the logarithm of the response category increments.

There is an almost linear relationship between discriminability and the logarithm of binocular disparity angles. The discriminability is most accurate at zero disparity, and decreases proportionately to the logarithm of disparity angles. Suggested angles of binocular disparity for equipment used are presented in the paper, as well as a discussion on the effects of disparity on target location on the horizontal dimension.

049 Cohen, J., & Dinnerstein, A. J. (1958). Flash rate as a visual coding dimension for information (WADC-TR-57-64). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-118 018)

The ability to discriminate flash rates was investigated. The flashes varied from one flash per four seconds to twelve per second. An analysis revealed that no more than five discriminable steps of flash rate could be utilized for encoding information. A further recommendation is that these five steps be spaced logarithmically to maximize discriminability.

050 Collins, B. L. (1982). <u>The development and evaluation of effective symbol signs</u> (NBS Building Science Series No. 141). Washington, DC: National Bureau of Standards.

Graphic symbols have recently been widely adopted for sign systems in the United States. Beginning with traffic sign systems, symbols have become widely used for applications ranging from products to buildings. In this report a brief history of the development of symbols is given, followed by a review of research on experimental evaluation of symbols. Some of the general advantages and limitations of symbols are discussed, along with graphic considerations essential in the development of effective symbols. Research on symbols for five areas of application -- highway, automotive/machinery, public information, product hazard, and safety -- is then discussed.

Finally, issues in the research and development of more effective symbols are reviewed. These include the need for good graphic design, characteristics of the intended user group, use of shape and color to encode information, and general visibility considerations.

051 Colson, K. R., Freeman, F. S., Mathews, L. P., & Stettler, J. A. (1974). <u>Development of an informational taxonomy of visual displays for Army tactical data systems</u> (Research Memorandum 74-4). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A082 951)

The research reported herein is an effort to develop a taxonomy of visual displays for Army Tactical Data Systems. The purpose of the taxonomy is to provide a framework or structure for defining, evaluating, and comparing displays based on user's information needs. An attempt was made to evaluate the taxonomy using operational display systems. In summary, the research reported here is representative of the process which occurs between the time the user intuitively senses that a human factors problem exists until resolution is obtained.

052 Connor, J. M. (1972). Effects of increased processing load on parallel processing of visual displays. <u>Perception & Psychophysics</u>, <u>12</u>, 121-128.

Three experiments were performed to determine whether displays processed in parallel would be processed serially if the information requirements in the task were increased. In Experiments 1 and 2, this increase consisted of an additional nonvisually confusing input. Mean reaction time increased, but parallel processing of the displays was still observed. In Experiment 3, the difficulty of the task was increased by including displays requiring fine discriminations. For both these visually confusing displays and the highly discriminable displays processed in parallel in Experiments 1 and 2, serial processing was observed.

053 Cooper, L. A. (1976). Individual differences in visual comparison processes. Perception & Psychophysics, 19, 433-444.

Two experiments are reported in which subjects compared the shape of two successively presented random visual forms. The first stimulus in the pair was one of five "standard" shapes, and the second stimulus was either the same as the standard or different by virtue of a perturbation in shape or an overall reflection. Marked individual differences were found in reaction time for the same-different comparison. For one type of subject "same" responses were faster than "different" responses, speed of "different" responses was unaffected by similarity of the test shape to the standard, and error rates and reaction times were not systematically related. For the other type of subject, "different" responses were generally faster than "same" responses, "different" reaction time decreased as the standard shape and the test shape became increasingly dissimilar, and error rates and reaction times were positively correlated. Implications of these individual differences for models of the same-different comparison process are discussed.

(From Perception & Psychophysics, 1976, 19, pp. 433-444. Reprinted by permission of Psychonomic Society, Inc.)

054 Crawford, A. (1962). The perception of light signals: The effect of the number of irrelevant lights. Ergonomics, 5, 417-428.

The experiment described was carried out to find the effect of the number of irrelevant lights on the human response time to light signals appearing amongst them. Both the signal lights and the irrelevant lights could be made steady or flashing; this produced four conditions of coding of the signal lights from the background, e.g. flashing signal with steady background and so on. It was found that the geometric mean response-time increased to an unusually large extent, from 0.8 sec with no background lights up to nearly 2 sec with 21. A background of flashing lights was found to increase the response-time more than a background of steady lights, whether the signal was flashing or not. The shortest response-times were obtained when flashing signals were seen against a steady background, and the longest with flashing signals against a flashing background. Thus it is concluded that flashing signals should not be used in conditions where a number of them may appear together within the field of view.

(From Ergonomics, 1962, 5, pp. 417-428. Copyright 1962 by Taylor & Francis, Inc. Reprinted by permission.)

055 Crawford, A. (1963). The perception of light signals: The effect of mixing flashing and steady irrelevant lights. Ergonomics, 6, 287-294.

A previous experiment has shown the danger of increasing the number of irrelevant lights in a driver's field of view and that the signal most easily seen is one which flashes while the irrelevant lights are steady. However, a flashing light

which may be an important signal to one driver may be irrelevant to other drivers in the vicinity.

A second experiment with the same general conditions as before has been carried out to find the effect of a mixture of flashing and steady irrelevant lights as a background to an essential signal.

It was found that the advantage gained by the use of a flashing light as a signal was lost if even one other light in the background was flashing. It was a definite disadvantage to have the signal flashing if three of ten irrelevant lights flashed, and when the number flashing was more than four, the ability to perceive flashing signals was seriously impaired.

(From Ergonomics, 1963, 6, pp. 287-294. Copyright 1963 by Taylor & Francis, Inc. Reprinted by permission.)

056 Crook, M. N., Hanson, J. A., & Weisz, A. (1954). Legibility of type as a function of stroke width, letter width, and letter spacing under low illumination (WADC-TR-53-440). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-56 537)

The legibility of small type as a function of letter width, stroke width, and letter spacing was measured for capitals and lower case under low and high illumination. Experimental type approximating a 6-point Gothic style was designed for the purpose. Speed and accuracy scores were obtained on a letter crossout task in part of the experimentation, and on an oral reading task in the remainder. Effects of the typographical variables were more marked under low than under high illumination. "Regular" letter width was considerably better than "condensed". For most of the varieties of type studies, stroke width was found to have an optimum in the neighborhood of 25% of mean letter width, and spacing an optimum at about 50% of mean letter width. Capitals could be read more readily than lower case when occupying the same printing area.

The results of this report are of value to the U. S. Air Force in that the basic principles can be applied to the design of aeronautical charts and check lists.

057 Dardano, J. F., & Donley, R. (1958). Evaluation of radar symbols for target identification (Technical Memorandum 2-58). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-158 180)

Five geometric forms considered for use as radar symbols were compared for discriminability. Frequency of symbols on the screen and proportion of the discriminated symbol to other symbols on the display were included as independent variables.

Twenty subjects were tested using an optical simulation of a radar scope. Omission of symbols to be discriminated in a limited screen exposure time as a criterion resulted in the cross within a circle, and a cross as most

discriminable, circle and half-circle less discriminable, and three quarters circle least discriminable.

Confusion between symbols was negligible and primarily due to the three-quarter circle as a background symbol interfering with the circle and half circle.

Ranking of symbols for ease of discrimination by subjects resulted in the same order as that based on errors of omissions.

058 Dardano, J. F., & Stephens, J. A. (1958). Discriminability of AAOC symbols (Technical Memorandum 4-58). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-200 845)

Relative discriminability of 4 geometric shapes considered for use as radar symbols, cross, cross-within-circle, circle, and half circle, were examined at size levels ranging for 1/8" to 1/2" at intervals of 1/16". The shapes were electronically generated by apparatus designed for installation in the Anti-aircraft Fire Control System M-33 PPI.

The cross and circle were more discriminable than the half circle and cross-within circle; these differences were independent of size level. Minimum size at which discriminability was not impaired lay between 3/16" and 5/16". At 2/16" size, there were extreme increases in scanning time and omissions for all symbols.

Subjects did not agree in their ratings of ease of discriminating each shape.

Some possible determinants of symbol discriminability are discussed.

059 Davis, C. J. (1968). Radar symbology studies leading to standardization (Technical Memorandum 5-68). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-668 649)

This report covers initial studies directed toward standardization of basic symbols representing "enemy," "friendly," and "unknown" targets on a radar scope. College students of both sexes and enlisted military men served as subjects.

In Experiment I, subjects assigned and ranked 68 geometric designs within the three meaning categories. Experiment II studied retention values after a short exposure to these same forms. Experiment III required all subjects to design a code differentiating the three meaning categories.

All significant findings on meaning were highly dependent on pictorials. Perceptual differentiation and ease of learning are recommended as the major dimensions of code design.

060 Davis, C. J. (1969). Radar symbology studies leading to standardization: II. Discrimination in mixed displays (Technical Memorandum 5-69). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-688 125)

This report covers continued studies toward standardization coding symbols for an information display. Experiments were directed toward locating "the most readily discriminated five-symbol code complex" as measured by errors and location times.

Experiment I attempted to simplify testing procedures by using a card sorting task. The same five-symbol code was presented as a black-on-white simulated display in Experiment II. Results were not comparable and the simulated display was used in further experiments with a variety of codes.

Legibility and association values of individual forms varied with the population of shapes within the code complex. Experimental results led to general recommendation for code design. Further studies are anticipated.

061 Davis, C. J. (1971). Studies leading to standardization of radar symbology: III. Discrimination in mixed displays, cathode ray tube presentation (Technical Memorandum 27-71). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-738 132)

This report covers continued experiments toward standardization of radar symbology. Ten code complexes previously used in paper and pencil tests have been replicated on a cathode ray tube (CRT). Each code consists of five geometric symbols representative of a display vocabulary.

Thirty subjects repeatedly selected individual symbols from a mixed display. Performance was measured in terms of errors and time to locate.

The best and worst codes confirmed paper and pencil experiments previously reported. Times and errors were consistently greater on the CRT. Symbol characteristics contributing to reduced efficiency are analyzed and tentative rules for CRT symbols are presented.

062 Deese, J. (1956). Complexity of contour in the recognition of visual form (WADC-TR-56-60). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-094 610)

The experiments reported here were aimed at the problem of finding out something about the influence of complexity of contour of visually presented forms upon accuracy of recognition of these forms. The results showed that, for forms made of abrupt, right-angled changes in contour, complex forms (those with many changes in the contour) are more accurately identified in an immediate recognition test than simple forms, if the observers are required to remember only one form at a time. If observers are required to remember 10 or 25 forms for recognition, simple forms are more accurately identified than complex forms. For forms with abrupt, varied-angled changes in contour, there is no difference in accuracy of recognition between simple and complex contours. This lack of a

difference between simple and complex contours for these forms is associated with a high incidence of reported verbal labelling or naming of the forms. This suggests that if observers can verbally code the forms, the relationships between complexity and recognition disappear. These findings led the author to the conclusion that forms which present relatively large amounts of information are more discriminable (unique), and are therefore easier to identify, but because they contain more information, they are harder to remember. If the observer is able to code forms with previously stored information, the information conveyed in the form may make little difference in a test of recognition. Thus, any attempt to reduce the information content of contours in order to facilitate memory for them may run into difficulty because of reduced discriminability among the forms. If the forms can be coded in terms of previously acquired information, however, both discrimination and retention may be facilitated.

063 Dewar, R. E., & Ells, J. G. (1977). The semantic differential as an index of traffic sign perception and comprehension. Human Factors, 19, 183-189.

There is a need to develop and validate simple, inexpensive techniques for the evaluation of traffic sign messages. This paper examines the semantic differential (a paper-and-pencil test which measures psychological meaning) as a potential instrument for such evaluation. Two experiments are described, one relating semantic differential scores to comprehension and the other relating this index to glance legibility. The data indicate that semantic differential scores on all four factors (evaluative, activity, potency, and understandability) were highly correlated with comprehension of symbolic messages. These scores were unrelated to glance legibility of verbal messages, but two factors (evaluative and understandability) did correlate with glance legibility of symbolic messages. It was concluded that the semantic differential is a valid instrument for evaluating comprehension of symbolic sign messages and that it has advantages over other techniques.

064 Donderi, D., & Case, B. (1970). Parallel visual processing: Constant same-different decision latency with two to fourteen shapes. Perception & Psychophysics, 8, 373-375.

Fourteen Os were shown 2, 5, 8, 11, or 14 geometric shapes at a 200-msec exposure. The maximum visual extent was the same for all numbers of shapes. The stimulus conditions were: all shapes identical, 1 shape different from the rest, and, for 5 to 14 shapes, 3 shapes different (4 shapes in all). The number of shapes, the condition, and the shapes used varied randomly through the sequence of 160 exposures. Decision latency to correct same or different response was independent of the number of shapes presented. Correct same and three-different

decisions were faster than one-different decisions, but with two shapes different decisions were faster than same. The results suggest that same-different decisions are made with information processed in parallel from many stimuli.

(From _*Perception & Psychophysics*_*, 1970,* _*8*_*, pp. 373-375. Reprinted by permission of Psychonomic Society, Inc.)*

065 Donderi, D. C., & Zelnicker, D. (1969). Parallel processing in visual same-different decisions. _Perception & Psychophysics_, _5_, 197-200.

Two to 13 geometrical shapes were exposed simultaneously to S who decided whether all shapes were the same or whether one was different from the rest. Correct different decisions were usually faster than correct same decisions, but latency was independent of the number of shapes presented. We conclude that input from all the shapes was simultaneously processed into either one or two shape categories, and that a decision-theory choice was made between "same" (one shape category and "different" (two shape categories) independent of the total number of shapes. This parallel processing is thought to be a characteristic of codable stimuli. Some observed same-different latency reversals were probably caused by a shift in the same-different criterion on the continuum for one- vs two-category decisions.

(From _*Perception & Psychophysics*_*, 1969,* _*5*_*, pp. 197-200. Reprinted by permission of Psychonomic Society, Inc.)*

066 Drury, C. G., & Clement, M. R. (1978). The effect of area, density, and number of background characters on visual search. _Human Factors_, _20_, 597-602.

In a search task, area of search field, density of background characters, and number of background characters are not independent. Many authors have found increases in search times with each of these factors but have not adequately controlled all three together. In this experiment, eight subjects searched a set of search fields covering combinations of all three variables. Search time was found to depend most heavily on number of background characters, but there were significant effects due to the other two variables. For a constant number of background characters, search time decreases as density increases. Direct visual lobe measurements confirmed these findings, which could have importance in visual inspection tasks.

(From _*Human Factors*_*, 1978,* _*20*_*, pp. 597-602. Copyright 1978 by the Human Factors Society, Inc. Reprinted by permission.)*

067 Dyer, W., & Christman, R. J. (1965). Relative influence of time, complexity, and density on utilization of coded large-scale displays (RADC-TR-65-325). Griffiss Air Force Base, NY: Rome Air Development Center. (DTIC No. AD-622 786)

A study was accomplished to demonstrate the influence of display coding on a task of locating and identifying specific entries in a numerical matrix. Various relationships among factors of matrix size, complexity, and viewing time were determined and are presented in graphic form.

In addition to demonstrating the expected efficacy of coding, several additional findings were revealed. It was found that coding is of particular value when search time is limited, and that as the difficulty of the task increases the value of coding also increases. It was also shown that with longer search times available, the relative value of coding appeared to increase. This finding was interpreted as the result of a two-stage data extraction effort: the first stage being a locating of the pertinent data entries, the second stage being the actual reading of the displayed values.

068 Earl, W. K. (1982). Learning and recognition of U.S., Soviet, and pictographic military symbology (Technical Report 583). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A138 884)

Twenty-seven military personnel, participated as interpreters. The experiment consisted of four phases. First, all interpreters received a brief session of familiarity training on the 19 military concepts used as the code list in the study. Second, the interpreters were divided into three groups of nine each and assigned to one of the codes. They were then given a paired-associate learning task where they learned the associations between the symbols and their concept names. Test trials were alternated with study trials and performance data was recorded to determine if learning performance was related to decoding performance. Third, the interpreters rated the 19 symbols along an eleven point scale of meaningfulness (0 to 10). Fourth, the symbol decoding task was administered using three sets of projector slides (one set for each code). Each set was comprised of three subsets according to the total number of symbols arranged randomly on a slide, i.e., 25, 50, or 75 per slide. Twenty percent of the symbols on each slide were copies of one type of symbol called a target symbol. Each symbol in the code appeared as a target symbol on a slide.

Each group of nine subjects was divided into three subgroups of three each. Each subgroup was assigned to one of three trial duration conditions which were long, medium, or short trial durations. A trial was started by the experimenter announcing the name of one of the 19 symbols thereby designating it as the target symbol to search for. Then a slide was projected. The decoding task was to search the projected slide (simulated CRT symbology displays) and detect and report all target symbols present on the slide during the time interval the slide was displayed. The trials were presented in continuous succession. They were organized into three blocks of 40 trials each. Each symbol appeared twice as a target symbol in each block. Each block presented slides from one of the three subsets of slides displaying either 25, 50, or 75 symbols per slide.

In the paired-associate learning task learning was significantly faster on the ARI experimental pictographic code than on either the U. S. or Soviet codes. There was no significant difference in learning rates between the U. S. and Soviet codes. There was little variation in rate of learning among the individual symbols in the pictographic code. In contrast, there was significant variation in learning rates among the individual symbols in the U. S. and Soviet codes.

Results from the symbol recognition task indicated that overall decoding performance was significantly superior under the pictographic code than under either the U. S. or Soviet codes. There was no difference between the U. S. and Soviet codes. Decoding performance was also significantly better under the long and medium trial times compared to the short trial time, and under the low symbol density level (25 symbols per slide) in comparison to the medium (50 symbols) and high (75 symbols) densities.

None of the correlations between performance measures for the three experimental tasks were statistically significant. These results indicate that symbol learning difficulty, meaningfulness ratings, and decoding proficiency may be independent functions. Neither symbol learning difficulty nor meaningfulness level show promise as predictor variables for symbol decoding performance.

069 Easterby, R. S. (1967). Perceptual organization in static displays for man/machine systems. Ergonomics, 10, 195-205.

The examination of some of the perceptual organization aspects of display design has led to the conjunction of three distinct but related approaches--the semantic/syntactic model based on language models, the uncertainty/structure model based on multivariate information theory, and an attempt to relate some fundamental aspects of form recognition to display design based on gestalt theory.

The views are in many ways conjectural and as yet unsubstantiated by any direct experimental evidence. They do, however, have the merit of having as their basis a considerable body of laboratory experimental work, particularly in respect of Garner's multivariate uncertainty model. They have not as yet been extended or extrapolated to applied problems of the human operator in complex systems, except in so far as the examples quoted have been successful in application, giving some support to the utility of these notions.

We may thus emphasize the following in relation to the design of display for man-machine system.
The importance of language models for static displays should not be overlooked.

Structure, both internal and external, is fundamental to display design and we need more investigation into the applied aspects of structure.

In terms of the operator's perceptual organization, the form of signification--geographical, operational or functional--must be carefully related to his task, particular in regard to S-R or concept task training.

It is to the unified theories of perception that we must look for our developing principles of systems display design. This, in conjunction with the language and information theory models, should enable some rational and more powerful tools for systems display analysis and synthesis.

(From Ergonomics, 1967, 10, pp. 195-205. Copyright 1967 by Francis & Taylor, Inc. Reprinted by permission.)

070 Egeth, H. E., Jonides, J., & Wall, S. (1972). Parallel processing of multielement displays. Cognitive Psychology, 3, 674-698.

The spatiotemporal characteristics of mechanisms that extract information from complex alphanumeric displays were investigated in a series of experiments using search and same-different detection tasks. Under several (but not all) experimental conditions the functions relating reaction time to the number of elements in the display were flat. Such data are consistent with a model in which individual elements are examined by independent parallel channels. Interestingly, this model was appropriate even in a search task in which the target was specified as any digit and the nontargets were a random assortment of letters.

(From Cognitive Psychology, 1972, 3, pp. 674-698. Copyright 1972 by Academic Press, Inc.)

071 Egeth, H. E., & Pachella, R. (1969). Multidimensional stimulus identification. Perception & Psychophysics, 5, 341-346.

In an absolute judgment task, total information transmitted about a set of stimuli increases as the dimensionality of the stimuli is increased. However, as the number of dimensions is increased, information transmitted about each component dimension decreases. Four factors were proposed that might, singly or in combination, account for this decrement: stimulus duration, interdimensional interference, distraction, and response complexity. The results of four experiments established that each of these factors may be operative under appropriate circumstances. It was also concluded that component dimensions were processed simultaneously rather than sequentially. However, the processing was not truly parallel because the input channels were not independent of one another.

(From Perception & Psychophysics, 1969, 5, pp. 341-346. Reprinted by permission of Psychonomic Society, Inc.)

072 Egeth, H. E. (1966). Parallel versus serial processes in multidimensional stimulus discrimination. Perception & Psychophysics, 1, 245-252.

Although considerable effort has been devoted to the description of processes underlying discriminations along single dimensions, there have been few attempts to determine whether or how these elementary processes are combined when discrimination requires the consideration of more than one stimulus dimension. In the present experiment, Ss were required to indicate whether two simultaneously presented multidimensional visual stimuli were identical or different. The response measure was reaction time, and Ss had a monetary incentive to respond both quickly and accurately. It was concluded that the most appropriate model for this task is one that assumes that dimensions are compared serially, and that the order in which dimensions are compared varies from trial-to-trial. Further, when a pair differs along several dimensions, Ss do not necessarily examine every dimension before initiating the response "Different."

(From Perception & Psychophysics, 1966, 1, pp. 245-252. Reprinted by permission of Psychonomic Society, Inc.)

073 Ellis, S. H., & Chase, W. G. (1971). Parallel processing in item recognition. Perception & Psychophysics, 10, 379-384.

It is shown that in Sternberg's item recognition task Ss need not make a judgment of the absolute size or color of the test item before comparing it with memory. However, Ss do use size or color information, when possible, to reduce long reaction times for large memory loads. The results suggest that Ss are able to scan memory for form in parallel with testing for gross stimulus features, like size or color. This finding has important implications for sequential two-stage theories of attention.

(From Perception & Psychophysics, 1971, 10, pp. 379-384. Reprinted by permission of Psychonomic Society, Inc.)

074 Erickson, R. A. (1964). Relation between visual search time and peripheral visual acuity. Human Factors, 6, 165-177.

An experiment conducted at the U.S. Naval Ordnance Test Station investigated the relationship between peripheral visual acuity and time required to locate a target in a static structured display. Sixteen male observers were used in the tests.

Peripheral acuity measured at 3.6 degrees and 4.8 degrees off the visual axis correlated significantly at the 0.01 level with time required to find a target in displays containing 16 or 32 rings and correlated at the 0.05 level with search time on displays of 16 and 32 blobs. Almost all correlations involving search times from object densities of 48 and/or acuity measurements made at 6.0 degrees off the visual axis were not significant.

In addition to the results concerning peripheral visual acuity, other relationships between variables were suggested by an analysis of the data. An analysis of variance established that the shape of the objects in the display (blobs or rings) and the number of objects in the display (16, 32, or 48) had a significant effect ($p<0.01$) upon search time. The interaction of shape and object density was also found to be significant at the 0.01 level. There were no significant intercorrelations between observer age, foveal acuity as measured in a naval eye examination, and peripheral acuity. Furthermore, age and foveal acuity did not correlate significantly with search performance.

075 Eriksen, C. W. (1952). Location of objects in a visual display as a function of the number of dimensions on which the objects differ. Journal of Experimental Psychology, 44, 56-60.

Speed in locating objects on a visual display was investigated under the following conditions: (*a*) When the various classes of objects on the display differed from one another on only one of the four visual dimensions of form, hue, size, and brightness; and (*b*) when the classes differed from one another on two or on three of these dimensions.

For the single dimensions, location time for hue differences was significantly faster than for form differences, and hue and form were both significantly faster than either brightness or size. The location times for the compounds of two and three dimensions were found to correspond to a weighted geometric mean of the single dimensions of which they were composed. Compounds involving both the form and size dimensions were an exception due to an interaction between these two dimensions.

076 Eriksen, C. W. (1953). Object location in a complex perceptual field. Journal of Experimental Psychology, 45, 126-132.

The present study was concerned with the perceptual variables that determine the speed with which designated objects can be located from among a large field of objects. Two variables, field heterogeneity and target definition, were studied. Field heterogeneity, as determined by the number of ways that the objects in the field differed from one another, was found to be an important determiner of location time. Location was quickest when the fields varied on hue, hue and form, and hue, form, and brightness, and slowest when the field was heterogeneous on hue, form, size and brightness, and form, brightness, and size.

Under comparable field heterogeneity, target objects that were multiply defined by assigning them unique values on each of several dimensions were located more rapidly than object defined on only one dimension.

077 Eriksen, C. W. (1955). Partitioning and saturation of visual displays and efficiency of visual search. Journal of Applied Psychology, 39, 73-77.

The present study was concerned with the effect of several characteristics of visual displays upon speed of visual search. The time required to locate a constant number of signals in a square display was determined when: (*a*) the number of irrelevant signals was varied from 10 to 70 and (*b*) the number of partitions of the display was varied by the use of grid lines. Grid lines were used to partition the display into a 9 X 9, a 13 X 13, and a 16 X 16 matrix.

The results show that search time increases both when the number of irrelevant signals is increased and when the number of partitions is increased. An explanation was advanced for these effects in terms of the number of foveal fixations required for signal identification and the use that observers make of grid lines in their plan of search.

078 Eriksen, C. W., & Eriksen, B. A. (1979). Target redundancy in visual search: Do repetitions of the target within the display impair processing? Perception & Psychophysics, 26, 195-205.

Two experiments tested the predictions from Bjork and Murray's (1977) extension of Estes' (1972, 1974) interactive channels model that repetition of a target within a display should, under certain conditions, impair or slow processing. These predictions were contrasted with those of the continuous flow model (Eriksen & Schultz, 1979) that, under the same conditions, repetitions should not impair processing and might possibly facilitate it. Experiment 1 evaluated the relative effects of feature similarity, variable target-noise spacing, and perceptual segregation in a response competition paradigm. In general, results favored the continuous flow conception and competition among internal recognition responses, and no evidence was found for impaired performance due to target repetitions. However, questions concerning possible facilitation arising from redundancy led to Experiment 2. In that experiment, trials were blocked by spacing or noise type. Again, target redundancy did not impair performance relative to the single target control. However, no facilitation effects were found.

079 Eriksen, C. W., & Hake, H. W. (1955). Multidimensional stimulus differences and accuracy of discrimination. Journal of Experimental Psychology, 50, 153-159.

The present study was concerned with the contribution of multidimensional stimulus differences to accuracy of discrimination. Discrimination accuracy was determined by the method of absolute judgment for a series of stimuli varying along the dimension of size, of hue, and of brightness. The discrimination measures obtained for these stimuli varying along these single dimensions were then compared with the discrimination measures obtained when a series of stimuli

varied on size and hue, size and brightness, hue and brightness, and size, hue, and brightness.

The results demonstrated that the discriminability for a multidimensional series of stimuli was considerably greater than that obtained for any of the compounding dimensions used alone. It was further shown that the discrimination accuracy for a compounded or multidimensional series of stimuli could be predicted with reasonable precision if the discrimination accuracy of the compounding dimensions was known. This predictability was based upon the assumption of independence in the accuracy with which magnitudes on two or more dimensions are simultaneously judged.

080 Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. Perception & Psychophysics, 25, 249-263.

This paper reexamines the visual search process, and visual information processing more generally, from a perspective of the continuous flow of information and responses through the visual system. The results from three experiments are reported which support the continuous flow conception: Information accumulates gradually in the visual system, with concurrent priming of responses. The first two experiments investigated the processing of display stimuli which varied in size and figure-ground contrast in a nonsearch task, and provided evidence confirming a continuous flow model. Experiment 3 employed an asynchronous onset of target and noise and provided convergent evidence of the accumulative nature of information and response priming in visual processing.

(From Perception & Psychophysics, 1979, 25, pp. 249-263. Reprinted by permission of Psychonomic Society, Inc.)

081 Estes, W. K. (1972). Interactions of signal and background variables in visual processing. Perception & Psychophysics, 12, 278-286.

Three variables which determine the opportunities for signal-noise confusions, display size (D), number of redundant signals per display (N), and number of alternative signals (A) were studied in relation to nature of the noise elements, confusable or nonconfusable with signals. Data were obtained in a forced-choice visual detection situation, the displays being linear arrays of letters on a CRT screen. For all three performance measures used, frequency of correct detections and correct and error latencies, strong interactions were obtained between all of the other variables and signal-noise confusability. The functions obtained, together with other data bearing on the role of confusions and on spatial relations among characters within the display, suggest a model whose initial phase is a parallel feature extraction process involving inhibitory relations among input channels.

(From Perception & Psychophysics, 1972, 12, pp. 278-286. Reprinted by permission of Psychonomic Society, Inc.)

082 Florence, D., & Geiselman, R E. (1986). Human performance evaluation of alternative graphic display symbologies. Perceptual and Motor Skills, 63, 399-406. Summary.

Nonmilitary subjects learned each of two types of foreground symbol sets (conventional symbols and iconic symbols) and were then shown a series of computer displays containing various symbol configurations. Each subject was required to search for specified foreground symbols under the conditions of high and low density of symbols, restricted and nonrestricted search, and pictorial versus nonpictorial target-symbol presentation. Iconic symbols yielded faster search times than conventional symbols under the condition of nonrestricted search and under the condition of nonpictorial target symbol presentation. These results suggest that iconic symbols are both easier to locate and easier to recall from memory. In addition, regardless of the type of symbology, high-density display increased search times. It was concluded that a system that incorporates both iconic symbols and selective call-up on foreground information would likely result in optimal human performance on search-related tasks.

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083 Foley, P. J. (1956). Evaluation of angular digits and comparisons with a conventional set. The Journal of Applied Psychology, 40, 178-180.

A new set of digits designed to make maximum use of easily discriminated forms was studied. Data on confusion errors are given. The legibility of the new digits is not independent of whether they are presented as black on a white ground or as white on a black ground. At low illumination levels white on black is more legible, the reverse being true at high illumination levels. Comparisons with a conventional set, the Mackworth digits, at different illumination levels, exposure times, and angles of view, show the new set to be significantly more legible under all of these conditions.

084 French, R. S. (1954). Pattern recognition in the presence of visual noise. Journal of Experimental Psychology, 47, 27-31.

Recognition of a "target" pattern of dots against a background of "visual noise" was studied as a function of both the number of target dots and the number of noise dots. Data were obtained for each number of target dots from 2-9, using 192 different combinations of random target patterns embedded in random noise patterns varying from 1-8 dots. The Ss were 192 basic trainees at Lackland Air Force Base.

The results indicate that increasing the complexity of the target pattern by increasing the number of elements improves recognition performance progressively. On the other hand, increasing the complexity of the visual noise produces a progressive decrement in recognition of the target. Increasing the number of elements in the target pattern beyond seven or eight seems to produce little if any further improvement in recognition performance. In general, recognition

performance improves as the ratio of number of target dots to number of noise dots increases up to a target-to-noise ratio of about 3:1.

085 Fried, C. (1959). A study of the effects of continuous wave jamming on the detection of antiaircraft operations center symbols (Technical Memorandum 9-59). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-228 979)

Detection time was studied for four geometric shapes, considered for adoption as Antiaircraft Operations Center Symbols, that were exposed to three degrees of simulated continuous wave jamming. The shapes studied were the Circle, Cross, Half Circle and Cross-Within-Circle. Their diameters remained constant at 5/16". The shapes were generated electronically on a Planned Position Indicator display.

Detection time increased for all four symbols as the intensity of continuous wave jamming increased, but this increase was not significant for the increase from the no noise to the mild noise level. All symbols, except for the Cross, had approximately the same detection time for each of the three noise levels. Any differences were not significant.

The number of errors made by the subject were small and did not show any trend.

The significantly lower detection time for the Cross at all noise levels is discussed.

086 Fried, C. (1960). Synthetic video as an electronics counter-counter measure: A study of pulsated and steady state symbology (Technical Memorandum 11-60). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-242 570)

A study was conducted to determine the effectiveness of pulsing a suggested Antiaircraft Operations Center (AAOC) symbol in overcoming the concealment effects of white noise jamming. Pulsing resulted in a flickering symbol on a Plan Position Indicator. Four degrees of jamming intensity were studied along with four flicker rates -- 0, 2, 4, and 8 cycles per second.

The psychophysical technique of method of limits was used to determine if flicker improved detection with a background of jamming. The results indicate that no advantage is gained in pulsing a synthetic symbol in overcoming the effects of jamming. A discussion of this result with a review of procedures is included.

087 Garner, W. R., & Hake, H. W. (1951). The amount of information in absolute judgments. Psychological Review, 58, 446-459.

1. With absolute judgments, or stimulus ratings of stimulus categories, the judgments of an *O* indicate how accurately the *O* perceived which of several alternative stimuli occurred on a particular presentation, or how much information the *O* obtained about which stimulus occurred.

2. The amount of information which the stimuli transmit to an *O* can be measured in bits.

3. This measure gives an estimate of the minimum number of stimulus categories which can be used to transmit the maximum amount of information in those cases where the stimulus is a symbol for a group of events, and where the coding of the events to the symbol can be done with no error.

4. The contingency coefficient has some of the same properties as the amount of information.

5. In order to select the stimuli for maximum information transmission a scale of equal discriminability is required, and a technique for constructing such a scale is described.

6. The scale of equal discriminability can also be used to select stimuli which will partially compensate for an unequal frequency distribution of the events being represented.

088 Geiselman, R. E., Landee, B. M., & Christen, F. G. (1982). Perceptual discriminability as a basis for selecting graphic symbols. Human Factors, 24, 329-337.

The purpose of this research was to develop a performance-based criterion for selecting among alternative symbols to be used in graphic displays. The specific criterion developed was an index of perceptual discriminability. Through regression analyses of an intersymbol similarity-rating matrix, it was concluded that symbols are judged more or less similar on the basis of the number of shared versus unique configural attributes (an X, a triangle, etc.), as opposed to primitive attributes (number of lines, arcs, etc.). An easy-to-use discriminability-index formula was derived from the regression analysis involving the configural attributes, and this formula was used to predict the results of an experiment involving a search for specific symbols embedded in an array. Indices obtained from a formula such as the one developed here could be used as part of the basis for choosing among alternative candidate symbols for inclusion in an existing symbol domain.

089 Gerathewohl, S. J. (1950). Investigation of perceptual factors involved in the interpretation of PPI scope presentations - Literature and introduction (Project No. 21-24-009, Report No. 1). Randolph Field, TX: USAF School of Aviation Medicine. (DTIC No. AD-86 866)

A survey was made of literature dealing with tests used for the selection of radar operators, psychological experiments in radar, and perceptual problems of PPI-scope interpretation. Figure-ground relationships, the phenomenon of figure development, the significance of contours, the perception of contrasts, and signal localization of the scope are discussed as basic problems in target identification. The contribution of Gestalt psychology to the problem of target identification is considered. General research problems which appear to be of importance include a perceptual analysis of the formation and development of signals on the PPI scope, investigation of the act of perception in recognizing targets, and an investigation of the time and space requirements for the recognition of targets on the PPI screen.

090 Gerathewohl, S. J. (1953). Investigation of perceptual factors involved in the interpretation of PPI scope presentations - Form discrimination under conditions of heavy video noise (Project No. 21-1205-0004, Report No. 1). Randolph Field, TX: USAF School of Aviation Medicine. (DTIC No. AD-19 692)

Experiments on target discriminability were made using the Supersonic Trainer AN/APQ-13 T1 and a radar set AN/APS-15 for presenting the targets at simulated distances of 10, 20, and 50 miles to 24 untrained observers under conditions of heavy background noise. The following results were obtained: (1) Significant differences in discriminability were found between the four forms. (2) The rank order was different from that obtained under favorable viewing conditions. (3) The discriminability of the targets may be influenced but slightly by their orientation and position on the target circle. (4) Target discriminability was definitely lower at the 50-mile range than at the other two ranges. (5) Differences between subjects were masked by the experimental conditions.

091 Gerathewohl, S. J. (1954). Conspicuity of flashing light signals of different frequency and duration. Journal of Experimental Psychology, 48, 247-251.

The experiments reported here have produced evidence that when S is engaged in a very complex psychomotor task, and does not know when and where a light signal may appear, its efficacy as a warning or indicator is determined not by the luminance of a single flash alone, but by the conspicuity of a series of flashes. The results suggest that, if the brightness contrast is 1.00 or 74.20, i.e., according to our previous findings, close to or larger than 1.00, S will respond to a series of light flashes in a complex situation with about the same speed whether the flash becomes visible only once each second for 1/2 sec., two times for 1/4 sec., or whether it occurs four times per second for only 1/8 sec. At the low contrast, however, the fast flashing light of short duration seems to be more conspicuous than the slow flashing signal of a longer duration.

092 Gerathewohl, S. J., & Rubenstein, D. (1952). Investigation of perceptual factors involved in the interpretation of PPI scope presentations. II. A pilot study of form discrimination (Project No. 21-24-009, Report No. 2). Randolph Field, TX: USAF School of Aviation Medicine.

Six basic planimetric forms (triangle, circle, rectangle, trapezoid, ellipse, and square) were used in an identification experiment by means of a Supersonic Trainer. Twelve targets of these forms were arranged in a target circle around the antenna and seen at ranges of 50, 20, and 10 miles from a simulated altitude of 26,000 feet. The targets were identified by 24 untrained subjects under conditions of rest. The following observations made: (1) significant differences in discriminability exist among these targets; (2) position on radar screens influences discriminability; (3) geometric shape seems to influence discriminability; (4) discriminability increases with increase in size of targets; and (5) significant differences in ability in target identification were found among the observers.

093 Goldstein, D. A., & Lamb, J. C. (1967). Visual coding using flashing lights. Human Factors, 9, 405-408.

An investigation of the feasibility of an alarm system employing visual signals was made. Using flash rate, values for four easily discriminable signals were established. In addition, minimum effective intensities for the four signals were obtained for the entire range of ambient illuminations associated with the operational situation. In a separate study, it was shown that little training was required to learn the signal code and once learned the code was maintained with little or no retention loss over the length of the experiment. The alarm system in its final form was used under both simulated work and actual shipboard conditions and was found to be effective as an attention-getting device and as a message source.

094 Gorrell, E. L. (1980). A human engineering specification for legibility of alphanumeric symbology on video monitor displays (rev) (DCIEM-TR-80-R-26). Ontario, Canada: Defence and Civil Institute of Environmental Medicine. (DTIC No. AD-A088 470)

Conventional human engineering legibility specifications for alphanumeric symbology displayed on video monitors consist of predictors of user performance derived from legibility research studies. Typical legibility predictors are symbol size, symbol luminance, contrast ratio, font, dot matrix dimensions, and pixel active area. This report discusses a number of significant problems associated with the development and application of conventional legibility specifications. In addition, it presents a detailed specification for comparative and objective evaluation of video monitor legibility performance

based upon legibility tests developed for the USAF. This specification consists of criteria for subject selection, visual environment design, display monitor setup, test material design and presentation, legibility task scores, and legibility test performance. It is to be noted that this report is a revision of an earlier report under the same title (DCIEM Tech. Report No. 79X01) published in January 1979. While the specification for the Legibility Test has not undergone any major change, the proposed Minimum Conventional Legibility Criteria have been reduced in number. The revised report also includes a new appendix describing in detail a standardized procedure for measuring CRT symbol luminance and calculating contrast ratios.

095 Gould, J. D. (1968). Visual factors in the design of computer-controlled CRT displays. Human Factors, 10, 359-376.

This paper is concerned with the important visual variables that determine image quality on computer-controlled CRT displays. A strategy is developed that leads to general conclusions about each variable even though most of these variables interact. For each variable considered, the recommended range of values is determined on the basis of experimental evidence and is compared with the values presently used on displays. Where discrepancies between these two exist, alternative solutions are mentioned. Conclusions are (i) presently used values of display luminance, chromaticity (color), and resolution are adequate; (ii) several displays flicker; (iii) characters are large enough but may be marginal in terms of number of elements; (iv) luminance contrast is not adequate.

096 Green, B. F., & Anderson, L. K. (1956). Color coding in a visual search task. Journal of Experimental Psychology, 51, 19-24.

Two experiments were reported in which search times for colored symbols (two-digit numbers) on a visual display were measured as a function of the relative number of symbols of each color, and the number of different colors used. When *Os* know the color of the target, the search time is approximately proportional to the number of symbols of the target's color. There is also a slight increment in search time due to the presence of the wrong-colored targets. When *Os* do not know the target's color, search time depends primarily on the total number of symbols on the display. However, search times are slightly longer for multicolored displays than for comparable single-colored displays.

097 Green, P. A., & Pew, R. W. (1978). Evaluating pictographic symbols: An automotive application. Human Factors, 20, 103-114.

Fifty university students participated in a laboratory experiment which examined 19 pictographic symbols previously used or proposed for labelling automobile controls and displays. Association norms, measures of familiarity, and magnitude

estimates of the symbols' communicativeness were collected. Twenty of these subjects also participated in a paired-associate learning task and a two-alternative, forced-choice reaction-time task in which they made same-different judgments in response to verbally presented symbol labels followed by visually presented pictograms. It was found that, in general, the relative order of merit for the individual symbols was not consistent across tasks. Specifically, ratings of communicativeness found to be well correlated with associative strength and to a lesser extent with reaction time, but associative strength was only weakly correlated with reaction time. Ease of learning was found to be an independent measure.

098 Green, P. A. (1979). Rational ways to increase pictographic symbol discriminability. Doctoral dissertation. Ann Arbor: The University of Michigan.

While automobile controls can be identified in many ways, (e.g., standardizing their location or shape), symbolic coding is the scheme most acceptable to the manufacturers. Because of the international nature of the automobile market, pictographic symbols, a language-free means of identification, are preferred over words or abbreviations. Many symbols, both existing and proposed (e.g., high and low beam), are visually confusable. By facilitating control-selection errors and increasing control-selection times, those confusions make driving more hazardous than it should be. The goal of this research was to compare several ways of increasing the discriminability of similar symbols.

Six alterations were considered; five modifications of symbol elements (changes in height to width ration, strokewidth, rotation in the frontal plane, repetition, and filling in an enclosed area) and substitution of a new symbol (new prototype) for one member of a confusable pair. The last four changes were compared in four studies.

In the first, magnitude estimates of symbol discriminability and two-choice response times (select a picture matching one previously displayed) were obtained for 12 drivers. There were 471 pairs of symbols for the headlights, windshield wiper and washer presented in the response-time task and a 372-pair subset in the rating task. The ratings, response times, and errors per symbol pair were all highly correlated (.65-.74). Those data showed differences in line angle (e.g., headlight rays and wiper blade) were most difficult to discriminate and new prototype pairs were easily differentiated. Differences in line number (e.g., number of light rays) and how much of each symbol was filled were also readily discriminated when those differences were extreme. Also, discriminability increased substantially as the number of dimensions on which symbol pairs differed increased.

To determine the effect of including confusable pairs of symbols in larger sets, symbols for several controls and displays (heater, air conditioner, vent, radio volume and tuning, exterior-lamp failure, and tire pressure) were developed. Suggestions for those symbols were drawn by 43 drivers in Experiment Two. Based

on those drawings the author designed several candidate symbols for each function. In the third experiment 62 drivers made magnitude estimates of how well each candidate's intended meaning was understood. From these data and existing standards a set of eight symbols was assembled.

In the final experiment, another response-time task, 351 pairs of headlights symbols along with either 0, 2, or 8 symbols for other controls were presented to 6 drivers. Response times and error data within and across set sizes were correlated (.40-.82). However, as the set size increased, fill differences became relatively more discriminable and new prototypes less. Response times to other members of the set were not affected by the confusability of the simultaneously presented headlights pair.

The predictions of symbol-pair discriminability made by several pattern-discrimination models (in particular, two spatial-frequency and one overlap model) were correlated (around. 40) with all of the dependent variables. (In the spatial-frequency model similarity depends upon the correlation of the amplitude spectra resulting from a two-dimensional Fourier transform of each image in question. In the overlap model, similarity is a function of the area two images share when placed on top of each other.)

In addition to providing recommendations of how to increase symbol discriminability, these studies showed that often model predictions of discriminability can replace experimental tests. Where tests are desired, either ratings or two-choice response times are appropriate except where symbol area is substantially altered. In that instance a four-choice response-time task is recommended.

099 Grice, G. R., Canham, L., & Boroughs, J. M. (1983). Forest before trees? It depends where you look. Perception & Psychophysics, 33, 121-128.

Because it may be deduced from the more elementary principles of visual processing, global precedence (Navon, 1977) is not a primary perceptual principle. Subjects were presented with a large letter made out of small ones and asked to make an identification response on the basis of either the large or small letter. When fixation was controlled to provide adequate stimulation from the small letter, there was no difference in reaction time (RT) between the large and small targets. Also, there was no difference in interference due to response incompatibility of the unattended letter based on target size. However, when the stimulus was presented peripherally, unpredictably to the right or left of fixation, RT was faster to the large target and interference was substantially greater for the small target. Functions for the development of associative strength and associative interference are presented. Global precedence is dependent on factors tending to degrade small stimuli more than large ones.

100 Hamill, B. W. (1984). Visual perception of structured symbols. Johns Hopkins APL Technical Digest, 5, 167-171.

A set of psychological experiments was conducted to explore the effects of stimulus structure on visual search processes. Results of the experiments, in which subjects searched for target stimuli among numerous other stimuli that served as distractors in stimulus displays, provide clear indications of interactive effects on visual search time of stimulus structure and the structure of the viewing context. Certain configurations were found that facilitated search and others that impeded search. Specific contexts were identified that influenced the speed with which target stimuli having particular structural characteristics may be found. These findings emphasize the importance of considering such relationships in selecting stimulus configurations for use as symbols in automated displays.

101 Hanes, R. M. (1949). A scale of subjective brightness. Journal of Experimental Psychology, 39, 438-452.

The fractionation technique has been used to obtain estimates of brightness for various time patterns and for various hues. Because of equipment limitations only the range from about 0.0001 to 100 millilamberts has been investigated thus far.

It has been shown that such estimates can be made consistently with only a reasonable degree of error.

The duration of the stimulus has been found to have no appreciable effect on these judgments so long as the stimulus duration is long enough to allow the sensation to reach a steady state.

Hue, likewise, has been shown to cause little change except, perhaps, at very low levels.

A subjective brightness or brilliance scale has been constructed and has been found to agree closely with the curve obtained by integrating DL's.

102 Hanes, R. M. (1950). Some effects of shape on apparent brightness. Journal of Experimental Psychology, 40, 650-654.

The influence of shape or form on apparent brightness has been investigated for three geometrical forms (square, triangle, and circle) at three intensity levels (0.1, 10, and 100 mL.). Comparisons were made only among forms of equal area.

The triangle and circle, on the average, exhibited an enhanced brightness relative to the square. These differences do not, however, remain the same for all sizes and all brightness levels. In other words, there are some significant interactions among the three factors. When the two smaller sizes are considered the triangle has a consistently higher apparent brightness than do the other two. For the largest size the circle appears to be brightest.

While the results can be partially explained in terms of marginal contrast and apparent size, no simple single explanation seems adequate to account for the results.

103 Harsh, C. M., & Craig, E. (1956). Exposure time and pattern complexity as factors affecting form discrimination (Technical Memorandum 178). San Diego, CA: Navy Electronics Laboratory. (DTIC No. AD-107 609)

The present study verifies the hypothesis that irregular, complex forms are misperceived and simplified on short exposures, indicating their undesirability for displays which must be read at a glance, or which are obscured by noise. This study is of interest primarily to persons investigating form perception in coded displays. The results are not directly applicable to display design without supplementary studies, and for this reason, it has been prepared in Technical Memorandum form for limited distribution.

104 Hart, S. G., & Loomis, L. L. (1980). Evaluation of the potential format and content of a cockpit display of traffic information. Human Factors, 22, 591-604.

Computer-generated displays of traffic information may be available in airplane cockpits within a decade. Many questions exist, however, about the impact of such displays on the air traffic control system. The purpose of the following studies was to design suitable display(s) to be used in simulation research aimed at answering these questions. The initial approach was to solicit opinions from general aviation and airline pilots about display format, information content, and symbology after they had viewed more than 100 candidate displays and display options.

The pilots' responses provided a preliminary indication of what information the potential user-population felt should be included in a traffic display. A series of later experiments was conducted to determine whether the features preferred in the pilot opinion survey would contribute to accurate and efficient pilot assessment of the spatial relationship between their own and another aircraft. A series of encounters between two aircraft were simulated in which the speed, heading, altitude, and geometrical relationship between the two aircraft were varied to allow a comparison between several graphic and symbolic formats for presenting information about the two aircraft.

105 Hawkins, H. L. (1969). Parallel processing in complex visual discrimination. Perception & Psychophysics, 5, 56-64.

In a "same-different" reaction time (RT) task pairs of stimuli varying along one or more dimensions are presented and S is required to indicate, as rapidly as possible, whether the stimuli are physically identical or different. This task was employed in three experiments investigating the processes by which multidimensional stimuli are discriminated. The results indicated that stimulus dimensions are compared in parallel; that the time required to interrogate a dimension varies randomly across trials and is dependent upon the time required to interrogate other dimensions present in test stimuli, and that comparisons terminate upon the detection of information sufficient for a correct response.

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106 Hawkins, J. S., Reising, J. M., Woodson, B. K., & Bertling, S. J. (1984). A study of programmable switch symbology. Proceedings of the Human Factors Society 28th Annual Meeting, pp. 118-122.

A multifunction switch is one way to solve the diminishing real estate problem in the modern cockpit. This study looked at pictorial coding of such a switch. Twelve different symbols were used, each with three levels of complexity and two levels of polarity. An error rate count was taken for subjects under both a naive and learned 50 millisecond exposure condition. This study demonstrated that there were three classes of symbols. These were: intuitive to the naive subject, intuitive to a learned subject, and non-intuitive, even to a learned subject. Complexity levels had a significant effect in only three of the twelve symbols. Polarity differences also had a significant effect in only three of the twelve symbols, although they were a different three. The overall conclusion is that the majority of symbols were intuitive after learning and robust to changes in complexity and polarity.

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107 Hawrylak, M. N., & Miller, J. W. (1985). Enhanced tactical symbology for command and control of ground forces (Master's Thesis). Monterey, CA: Naval Postgraduate School. (DTIC No. AD-A155 487)

This thesis is directed at the design and evaluation of "enhanced" ground-force map symbology. Enhanced symbology differs from conventional in that enhanced symbols quantify and clarify information on particular units such as combat effectiveness, personnel strength, equipment density and logistics readiness.

A variety of design properties compiled from several sources that should be considered when fashioning a new military symbol group is discussed with special

emphasis on reducing the negative effects of clutter. A suggested symbol set is developed for support of tactical decision-making and for display on computer graphics systems.

The performance of this symbology is then evaluated through an experiment designed to compare the process of quickly and easily solving tactical problems with the enhanced decision aids versus the conventional. An analysis of the experiment results indicates that a commander can reach a tactical decision faster using enhanced symbology.

108 Heinemann, E. G. (1955). Simultaneous brightness induction as a function of inducing- and test-field luminances. Journal of Experimental Psychology, 50, 89-96.

By means of binocular matching method, simultaneous brightness induction was studied as a function of test- and inducing-field luminances. The test field was disc shaped and was surrounded by a contiguous annular inducing field.

In the two experiments *S* made brightness matches between a test field and a comparison field of the same size and shape. In Exp. 1 the comparison field was presented against a completely dark background and *S* varied the luminance of the comparison field to make the match. With this procedure the effect of inducing fields whose luminance exceeds that of the test field by more than approximately .1 log unit cannot be measured; for inducing fields of greater luminance the test field appears darker than the comparison field for any suprathreshold luminance of the latter.

The effect of inducing fields of luminance greatly in excess of the test-field luminance was measured when the comparison field was made darker by surrounding it with an illuminated annulus. This was done in Exp. 2. The procedure of Exp. 2 differed from that of Exp. 1 in that *S* made the matches by varying either the luminance of the test field or of the inducing field surrounding the test field.

It was found that inducing fields of luminance much lower than the test-field luminance slightly *enhance* the visual effect of the test field. Inducing fields of luminance almost as great or greater than the test-field luminance *depress* the visual effect of the test field.

Possible theoretical interpretations of the results and the application of the results to the analysis of brightness constancy are discussed.

109 Hemingway, P. W., & Kubala, A. L. (1979). A comparison of speed and accuracy of interpretation of two tactical symbologies (Technical Report 389). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A075 428)

This report compares the speed and accuracy of interpretation of two tactical symbologies. One set of symbols was the standard set described in U.S. Army Field Manual 20-30. The other set was designed on the basis of previous research in symbology. A brief battle scenario was selected and for each symbol set 35mm

slides were prepared representing updates in a tactical display. Results showed that (a) accuracy of interpretation did not vary between the sets, (b) the author-designed set was interpreted more rapidly, and (c) female participants were more rapid in interpreting the displays than male participants.

110 Hemingway, P. W., Kubala, A. L., & Chastain, G. D. (1979). Study of symbology for automated graphic displays (Technical Report 79-A18). Alexandria, VA: U.S. Army Research Institute for Behavioral and Social Sciences. (DTIC No. AD-A076 916)

An extensive literature survey indicated a great variety of available alternative symbology formats. Before a specific format is selected, the necessary information requirements for a particular position must be determined. For Army tactical displays, this information should be gathered in experiments using realistic battle scenarios. As a related effort, alternative symbol formats were evaluated by civilians. Naive subjects generally preferred a pictorial symbol over traditional military alternatives. The report is written for a military audience.

111 Hillix, W. A. (1960). Visual pattern identification as a function of fill and distortion. Journal of Experimental Psychology, 59, 192-197.

Stimuli were constructed in a 10 X 10 grid by a random sampling procedure. The number of elements filled in was varied in steps from 10% through 50%, and the number of elements rearranged from the standard stimulus to make the correct alternative was varied from 10% through 40%. The combination of fill and distortion resulted in 20 stimulus classes. The *Ss'* task was to choose the stimulus that most closely resembled the standard from the three alternatives presented. Each of 120 Lackland Air Force Base trainees had all 20 stimulus conditions. Fill, distortion, and their interaction all had significant effects on time to respond and on number of correct responses. An "index of relative similarity" was developed to "predict" problem difficulty, and showed a close relationship to both number of correct responses and time to respond. Some further suggestions were made for the quantification of perceptual difficulty.

112 Hitt, W. D. (1961). An evaluation of five different abstract coding methods--experiment IV. Human Factors, 3, 120-130.

The purpose of this study was to ascertain the relative effectiveness of selected abstract coding methods, based upon their effects on various operator tasks. Five different coding methods were selected: numeral, letter, geometric shape, color, and configuration. Secondary variables included in the study were target density, number of code levels, and operator tasks. It was found that numeral coding and color coding are the two superior coding methods. If greater emphasis is to be placed on identifying symbols, numeral coding is superior to color

coding. No significant differences were found, however, between numeral coding and color coding for the remaining operator tasks: locating, counting, comparing, and verifying.

(From Human Factors, 1961, 3, pp. 120-130. Copyright 1961 by the Human Factors Society, Inc. Reprinted by permission.)

113 Honigfeld, A. R. (1964). Radar symbology: A literature review (Technical Memorandum 14-64). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-461 180)

This literature review was undertaken to summarize the state of the art of symbology in radar display systems. It reviews the various techniques for coding, extracts general principles for use in designing radar systems, and recommends areas for further research.

114 Horton, G. P. (1949). Target shape and accuracy on a schematic PPI display (USAF-TR-5962). Wright-Patterson Air Force Base, OH: Air Materiel Command. (DTIC No. AD-65 835)

Thirty subjects were presented individually with schematic PPI (polar coordinate) displays. These subjects were relatively naive. They had not had previous radar experience, but they were taught the principles of the PPI display and given training in locating targets on this schematic PPI. Each subject was required to estimate the location of 108 targets. Thirty-six of these targets were circles, 36 were ellipses, 36 were arcs. The arcs, circles, and ellipses were chosen on the basis of their perceptual equivalence. Each subject was requested to give the locations of these targets to the nearest mile and to the nearest degree. In addition to this study of the effect of shape of target on accuracy, the question of reading miles first and reading degrees second versus reading degrees first and reading miles second was also studied.

(1) The shape of the target has no demonstrable effect on the accuracy of locating the target when the target appears as part of the schematic display employed in this experiment.

(2) Miles are read with consistently greater accuracy than degrees.

(3) Reading miles first and degrees second gives superior accuracy in locating the target.

115 Howell, W. C., & Fuchs, A. H. (1968). Population stereotypy in code design. Organizational Behavior and Human Performance, 3, 310-339.

The present paper is concerned with the development of efficient signs or symbols for use in visual communication. In particular, it describes and illustrates a technique for generating such signs, and presents a series of experiments

undertaken to evaluate this technique. Although the application of these methods was limited to a specialized set of concepts (military intelligence terms), and the test experiments for signs developed were highly selective, it was believed that the principles involved have implications for several rather divergent areas of psychology which share an interest in language and communication.

(From Organizational Behavior and Human Performance, 1968, 3, pp. 310-339. Copyright 1968 by Academic Press, Inc.)

116 Howell, W. C., & Kraft, C. L. (1959). Size, blur, and contrast as variables affecting the legibility of alpha-numeric symbols on radar-type displays (WADC-TR-59-536). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-232 889)

The purpose of this study was to determine the functions relating size, blur, and contrast, and their interactions, to legibility of alpha-numeric symbols on a radar-type display.

Twelve subjects served under all 64 conditions obtained by combining factorially four levels of each of three variables: size, blur, and contrast. The stimuli, 36 alpha-numeric symbols, were projected on a ground-glass screen one at a time at a rate controlled by the subject's verbal responses. Instructions stressed equally speed and accuracy. Performance indices were information transmitted, speed, and accuracy. Confusion data were also reported for specific conditions.

The results indicated that each of the three variables and two of the interactions significantly influenced legibility. Optimum legibility was obtained at 26.80-min. size, high contrast, and low blur. Larger sizes frequently degraded performance.

The implications and possible generality of these data are discussed.

117 Ingling, N. W. (1972). Categorization: A mechanism for rapid information processing. Journal of Experimental Psychology, 94, 239-243.

It is hypothesized that under certain conditions *S*s are able to encode stimuli by category immediately, without first making a more complete identification, and that such encoding can produce a relative increase in the rate of processing. Results of an experiment support the hypothesis by indicating that *S*s can respond to a category task more quickly when they are not required to know the specific identity of symbols than when they are required to know the identity. Tests for confounding effects of general physical features were not significant in the design used.

118 Jacober, R. P., Jr. (1982). Standardization of map symbology (Paper presented to the 19-23 September 1982 convention of the American Society of Photogrammetry). Washington, DC: Defense Mapping Agency. (DTIC No. AD-A117 530)

In order to effectively communicate, man must have a common language. In the conventional or digital cartographic sphere, this axiom is no less true. Symbols form the language of cartography. Ideally, a worldwide standard set of symbols would solve many of the communication problems. But, this ideal solution is not technically feasible. However, within scale families of maps, standard symbology should be sought, especially in computer cartographic applications. This paper addresses the need for a standard for map symbology, particularly large scale maps, and suggests such a standard.

119 Jarosz, C. J., & Rogers, S. P. (1982). Evaluation of map symbols for a computer-generated topographic display: Transfer of training, symbol confusion, and association value studies (Technical Report 459-5). Santa Barbara, CA: Anacapa Sciences, Inc.

This report describes three studies conducted to evaluate the effectiveness of map symbols for a computer-generated topographic display. The criteria for developing symbol effectiveness were transfer of training, potential confusion, and association value.

A computer-generated topographic display, or CGTD, utilizes a cathode ray tube (CRT), or other electronic display, to present map-like information. Conventional map symbols often are inapplicable with a CGTD because the matrix of display elements, or "pixels" does not provide sufficient resolution for portraying small and detailed shapes. As a part of the research described in this report, design guidelines were developed for creating symbols that meet the limitations of a pixel matrix display. Sixty-nine topographic and tactical symbols were developed for the candidate symbol set.

The evaluation of symbol effectiveness was conducted by means of three surveys completed by military personnel. In Task One, the participants compared the map symbols in the candidate set with the symbols in the current set to determine if similarities existed. Because the participants could view both symbol sets in their entirety, the matching task was the analog of a transfer of training study in which the participants had "perfect recall." Similarity of a candidate symbol and its intended current symbol indicated positive transfer of training, while similarity of a candidate symbol and an unintended current symbol indicated negative transfer of training.

In Task Two, the participants compared symbols within the candidate set to determine if similarities existed. Similarity of any two symbols indicated potential for confusion.

In Task Three, the participants matched verbal definitions with candidate symbols. The frequency with which a candidate symbol was paired with its intended verbal definition is operationally defined as the symbol's association value. Symbols paired with their intended definitions had positive association value.

Numeric scores for each candidate symbol were derived from the survey data. Quotients for the three criteria--transfer of training, potential confusion, and association value--provided a means for evaluating the effectiveness of the candidate symbols. The results provided reasonably clear distinctions among classes of symbols.

Recommendations are provided for evaluating and modifying individual symbols.

120 Johnston, D. M. (1965). Search performance as a function of peripheral acuity. Human Factors, 7, 527-535.

This study was made to investigate the relationship between the size of visual fields of observers and time required to locate targets on static displays. The findings, which indicate that people with large visual fields can find targets more rapidly than observers with small fields, have practical selection and training application. Equations are presented which can be used to determine search time that can be expected as a function of the size of the visual field of the observer and the apparent size of the area being searched.

121 Jones, M. R. (1962). Color coding. Human Factors, 4, 355-365.

Research published in the last decade on color as a coding device is discussed. The method of absolute judgment yielded similar findings with respect to identifications of surface and luminous hues. These findings suggest that a reliable unidimensional hue code should not contain more than about eight optimally spaced stimuli. Variations in purity and luminance in addition to wavelength can significantly increase the number of usable code categories. However, criteria for code selection in a given situation should depend not only upon the number of visual objects to be differentially identified but also upon the type of task for which the code functions. In particular, color codes do not appear to be suited for situations that demand rapid and precise identification, whereas they are valuable in decreasing search-time with locate-type tasks.

122 Kafurke, P. (1981). An evaluation of the effectiveness of color coded tactical symbology applied to military maps (Master's Thesis). Monterey, CA: Naval Postgraduate School. (DTIC No. AD-A109 675)

This thesis examined the effect of using color coded tactical symbology on military maps. It reviewed the basic aspects of color coding techniques and described a task paced experiment in which conventional monochrome (blue vs. red) coding techniques were compared to multiple color coding. The multicolor coded stimuli used were 5 standard symbols representing Artillery, Armor, Infantry, Mechanized Infantry and Engineers. The symbols were coded red, green, blue, orange and black respectively. The analysis of the data obtained from 20 subjects revealed that performance under multicolor coding condition was significantly superior with respect to response time, accuracy of response and accuracy of location transfer onto a copy of the displayed map.

123 Kanarick, A. F., & Petersen, R. C. (1971). Redundant color coding and keeping-track performance. Human Factors, 13, 183-188.

An investigation was conducted to determine if performance on a keeping-track task could be enhanced by redundantly coding the displayed information channels that were being updated. At set intervals, the subject was interrogated about the status of any one of the information channels. The information consisted of numbers, colors, or numbers on a colored background, the last being the redundantly coded material. The three variables studied were channel value, payoff ratio, and coding condition. Results indicated that redundant coding did not aid performance; rather, it provided the subjects extra cues and increased the number of strategies that were used. As in previous studies, selective attention to the high-valued channels was a function of channel value and payoff ratio.

124 Karsh, R., & Mudd, S. A. (1962). Design of a picture language to identify vehicle controls: III. A comparative evaluation of selected picture symbol designs (Technical Memorandum 15-62). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-289 544)

This study investigated the accuracy of identification of each of 90 picture-symbol designs with each of 34 vehicle control names. Two sets of designs were evaluated. The set which had been empirically derived in a preceding study was found to be more effective than the set which had not been empirically derived. Effective symbols were found for 24 out of 34 vehicle control names. Ten new symbols have been developed. They will be presented subsequent to further evaluative tests.

125 Keates, J. S. (1972). Symbols and meaning in topographic maps. International Yearbook of Cartography, 12, 168-181.

The article discusses the informational content of topographical maps. It considers the notion that information which is provided by a map should allow a user to extract the most important features at first glance and the less salient ones upon demand. In addition, the concept of tailoring maps to a user's specific needs is also covered.

126 Kinchla, R. A., & Wolfe, J. M. (1979). The order of visual processing: "Top-down," "bottom-up," or "middle-out." Perception & Psychophysics, 25, 225-231.

This paper deals with the order in which different levels of form are recognized in a visual image. An experiment is reported in which the size of a tachistoscopically viewed image was varied. The results suggest neither an invariant "top-down" (gross shapes first followed by lower-order details) or "bottom-up" (the opposite) sequence. Rather, they seem to suggest a sort of "middle-out" sequence: forms at some intermediate level of structure having an optimal size or spatial-frequency spectrum are processed first, with subsequent processing of both higher and lower levels of form.

127 Klemmer, E. T., & Frick, F. C. (1953). Assimilation of information from dot and matrix patterns. Journal of Experimental Psychology, 45, 15-19.

An experiment was designed to demonstrate the application of information measure to a simple visual perception and to find the maximum information about a two-dimensional spatial location which can be assimilated from a brief visual exposure. The stimuli consisted of one or more dots within the outline of a square. This pattern was flashed on a projection screen for .03 sec. The *Ss* reported the positions of the dots by making marks in corresponding positions on answer sheets printed with the outline of a square and containing internal grid lines. The dots were positioned on the projected slide in positions corresponding to centers of cells in the *S's* answer matrix. Using a single dot, the order of the matrix on the *S's* answer sheet was increased from 3 X 3 to 20 X 20 in separate tests without changing the outside dimensions of the square. Using a 3 X 3 matrix the number of dots on each slide was increased from one through four in separate tests. The data were scored in terms of the amount of information successfully transmitted by *S* from the screen to his answer sheet.

1. The *Ss* transmitted a maximum of 4.4 bits of information about the position of a single dot in a square from a .03-sec. exposure.

2. The information transmitted increased with the number of dots used to at least 6.6 bits per exposure for four dots.

3. Combining the one-, two-, three- and four-dot slides into a single series did not result in less accuracy than when each number of dots was shown separately. Because of the increased number of alternatives, however, the information transmitted increased to 7.8 bits per exposure.

4. Including internal grid lines on the projected square had no effect on the information transmitted.

5. Removing the internal grid lines from *S*'s answer sheet had no effect upon the information transmitted by a single dot.

128 Knapp, B. G. (1983). Production method for designing tactical symbols: A case study (Working Paper 83-2). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Two key findings are immediately evident from this application of the production method for designing new symbols. First, the method is simple, low-cost and efficient to employ. Turn around time from step one through step four is less than four weeks. Second, simple visual inspection of symbol elicitations for each concept allows immediate grouping of some symbols with each other, since they appear quite similar.

129 Knapp, B. G. (1984). Scaling military symbols: A comparison of techniques to derive associative meaning. Proceedings of the Human Factors Society 28th Annual Meeting, 1, 309-313.

The use of symbolic representations of concepts is explored in the context of their inherent, associative meaning. Several symbol sets in military use were evaluated using two scaling techniques, ratings and pair comparisons. Findings validate a model of symbol categorization proposed by Modley (1966) and provide implications for the use of ratings vs. pair-comparisons in evaluating symbols.

130 Knapp, B. G. (1985). The precedence of global features in the perception of map symbols. Proceedings of the Human Factors Society 29th Annual Meeting, 1, 287-291.

This research was an investigation of how global processing of visual stimuli affect the speed and accuracy of map symbol perception in a search and locate task. It addresses the role of symbol structure in detection on maps, which is critical for prescribing how symbols should be designed and used. Symbols were scaled according to global and local features, and then detected as targets against a realistic map background. Globally and locally similar symbols were most distracting to each other as measured by response time, but not so for

accuracy. The importance of local features for this type of task was the most critical finding.

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131 Knapp, B. G. (1986). Symbology sourcebook for military applications (Research Note 86-74). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A172 035)

The purpose of this document is to provide an up-to-date reference of all available military symbols currently being used. This listing is preceded by a summary of recent ARI research efforts in the area of the design and use of military symbology. The research efforts proceeded in three stages. The first stage required the collection and organization of many currently used military symbols to allow comparisons and identify conflicts. This catalog included the Army Field Manual 21-30 and was the basis for a comprehensive database of military symbols, known as TACSYM. TACSYM and several other sources (not compiled by ARI) are listed in this document.

The second research stage was a survey of user's symbology needs. It revealed two major issues: (1) symbols did not exist for many concepts, and (2) therefore, users developed their own personalized illustrations for the concepts, resulting in a myriad of symbols representing the same concept. The third research stage was to experimentally investigate how to best develop and portray military symbols. Symbol characteristics such as perceptual discriminability, associative value, and configuration have been found to affect symbol detection. A systematic technique for choosing among alternative symbols was developed and procedures for designing new ones are presently being investigated.

132 Kopala, C. J., Reising, J. M., Calhoun, G., & Herron, E. (1983). Symbology verification study (AFWAL-TR-82-3080). Wright-Patterson Air Force Base, OH: Air Force Wright Aeronautical Laboratory. (DTIC No. AD-A131 328)

This study was performed to evaluate a proposed symbology set for real time combat situation displays in fighter aircraft. The primary objective was to compare pilot performance under two different coding conditions: shape coding only and both color and shape coding. Color coding was found to significantly reduce overall average response time, with this effect becoming more pronounced with increasing symbol density. The second purpose of the study was to compare performance differences among the symbol types for each of the three states (friendly, unknown, or hostile). Data on this topic is evaluated and possible explanations for discrepancies are noted.

133 Koponen, A., Waters, R. H., & Orlansky, J. (1952). The associational value of aeronautical chart symbols (ONR-TR-641-05-07). Stamford, CT: Dunlap and Associates. (DTIC No. AD-199 154)

The purpose of this study is to develop procedures by which meaningful aeronautical chart symbols, insuring rapid and efficient chart reading, can be devised and evaluated. The associational values of chart symbols were determined through five consecutive steps: (1) collection of samples of original symbols for a series of objects, (2) separation of these symbols into five general categories, (3) determination of the best symbol in each category for each object, (4) determination of the rank order preferences for each object, and (5) comparison of the selected symbols with conventional symbols. With the exception of step two, these steps were carried out through the use of tests administered to Naval and civilian subjects. Step two was accomplished through the examination and classification of the responses obtained in step one.

On the basis of the results obtained through these five steps, the symbols appearing on WAC charts were evaluated by the authors with respect to their associational values.

134 Kreifeldt, J. G. (1980). Cockpit displayed traffic information and distributed management in air traffic control. Human Factors, 22, 671-691.

The technical feasibility of graphically displaying information such as surrounding aircraft and navigation routes in the cockpit on a cathode ray tube has been suggested as a viable method for improving the safety, orderliness, and expeditiousness of the air traffic control system by distributing some of its management to the pilots equipped with this cockpit displayed traffic and navigation information (CDTI). Several years of experimental study of this concept, using a three-cab simulator facility at NASA-Ames, have produced several consistent findings relating to system performance and pilot and controller work loads and opinions. These findings generally agree with those from other studies.

The most consistent result is a considerable reduction in controller verbal work load without any appreciable increase in pilot verbal work load, although they may report an increase in visual work load. However, pilots tend to prefer distributed management to centralized management, while this is generally reversed for controllers. The reduced response delays in the system obtainable using CDTI permit pilots to maintain their own spacing more closely and precisely than when depending entirely upon controller-issued radar vectors and speed commands. As a result, time between successive aircraft landings and its variability can be reduced, thereby increasing runway utilization. Limited findings suggest that CDTI-based benefits do not detract from system safety.

On balance, distributed management offers significant advantages for air traffic control.

135 Krulee, G. K., & Weisz, A. (1955). Studies in the visual discrimination of multiple-unit displays. Journal of Experimental Psychology, 50, 316-324.

Four experiments have been reported on the determination of distance thresholds for 1-, 2-, and 3-digit displays as a function of the number of alternative possibilities in each position of the display. In the first experiment, eight categories were defined in terms of 1-, 2-, and 3-digit codes using different choices of elemental symbols to define three such sets of codes. With two of the three sets, results were obtained indicating this threshold is directly related to the amount of information contained in the most complex of the three positions. For the third set, the apparent difficulty of the specific binary choice chosen for the 3-digit code made this the most difficult of the three codes in the set. In a second experiment, thresholds for several binary choices used both as 1-digit and as 3-digit displays were obtained. With five out of six such comparisons no significant differences could be detected for the 3- vs. the 1-digit binary choice.

In the final two experiments, an alphabet of 32 symbols was used in order to investigate the relationship of threshold magnitude to amount of information, provided that only single-position displays were used. Increases in threshold were obtained in 8 vs. 16 and 16 vs. 32 categories when the comparison was based upon the discrimination of a set of alternatives first in isolation and finally as part of a larger set of alternatives. The data indicate that such threshold increases are not necessarily obtained when the larger set does not contain as members the specific symbols included in the smaller.

136 Kurke, M. I. (1956). Evaluation of a display incorporating quantitative and check-reading characteristics. The Journal of Applied Psychology, 40, 233-236.

By use of a card-sorting experiment, a comparison of three dial designs was made from the standpoint of accuracy and the speed of check-reading. Within the limits of this experiment, it was demonstrated that the conventional method of red lining a dial to indicate a deviation from "safe and normal" operation is significantly better than no "red-line" indication at all provided the criteria are errors, or reading time isolated from associated motor activity. It was also demonstrated that the experimental dial design principle is significantly more efficient than the other two, regardless of the three measures used in comparison. It is suggested that the experimental dial design is more easily read due to the fact that a simpler form of visual discrimination is required than for the task of reading the other dials.

137 Landee, B. M., & Geiselman, R. E. (1984). Graphic portrayal of battlefield information: Executive summary (Research Report 1369). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A153 225)

Key findings from the three tasks--(1) compilation of automated symbol catalog; (2) user survey of needs for symbolized information; (3) discriminability

technique for choosing among conflicting symbol alternatives--are described and incorporated into a plan for standardizing tactical symbols. The integration of these findings offers a succinct and useful summary of current progress toward the development of a standard set of tactical symbols, and a proposal for the investigation of problems in developing ADP compatible (communication) symbology.

138 Landee, B. M., Geiselman, R. E., & Clark, C. S. (1981). Military symbology: A user-community survey (Technical Report 582). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A138 921)

The primary purpose of the work described in this report is the identification of military concepts that currently do not have a standard method (FM 21-30) of graphic portrayal. A secondary purpose is to examine nonstandard methods for portraying concepts.

Military officers were asked to generate their requirements for information on a situation display as they worked through a tactical scenario. They were then asked to assess how well the information requirements identified could be portrayed by the Army standard symbology, FM 21-30. The information requirements were obtained from survey sessions in the form of questions and answers; these data were then organized and summarized by the application of a semantic cluster analysis. Instances of non-standard (personalized) methods of portraying the required information were also recorded.

A total of 839 tactical questions were generated during 14 elicitation sessions. Survey participants classified 29% of the information to be obvious from a display with conventional symbology, 28% to be obtainable by inference, and 43% of the information to be unavailable from a display. Further, 30% of the information requirements obtained had been displayed with non-standard (personalized) portrayal methods. Four cluster analyses of the tactical questions were conducted and five major military concepts were identified which are not contained in FM 21-30, but are being graphically portrayed by various users. The major concepts identified from the cluster analyses include status, capability, availability, threat, and logistics. Additional concepts were identified on the basis of their hig, incidence of personalized portrayal. Research findings indicate a need for an update of FM 21-30, both for portraying new concepts, such as equipment and weapons, as well as addressing those concepts as dynamic aspects of the battlefield.

139 Landee, B. M., Samet, M. G., & Foley, D. R. (1979). A task-based analysis of information requirements of tactical maps (Technical Report 397). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A086 502)

A task-based approach for specifying and analyzing map information requirements was developed and demonstrated. A review of selected literature concerning the mapping process included methods for selecting environmental data to be shown on a map. Seven tactical tasks, representing common battlefield functions performed

by different users and echelons were sampled and analyzed in depth. A military role-playing and doctrinal verification procedure was used to divide tasks into subtasks so that corresponding information requirements could be specified. Each subtask, in turn, was broken down into basic tactical questions about the environment. The data required to answer each question defined the information categories and levels of detail necessary for successful task completion.

The resulting map-related information requirements were synthesized to generate representative map development guidelines. This synthesis--which emphasized information about vegetation, road networks, and built-up areas--was accomplished across tasks to identify those specific information needs which show either prominent commonality or uniqueness with respect to different tasks and user groups. Within the framework of these task-based comparisons, examples illustrate the types of implications that can be derived from the task-based analysis of information requirements.

140 Landee, B. M., Samet, M. G., & Gellman, L. H. (1980). User-elicited tactical information requirements with implications for symbology and graphic portrayal standards (Technical Report 497). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A110 161)

The primary purpose of this research was to elicit and organize selected battlefield information requirements of the command staff, and to examine the adequacy of conventional symbology for satisfying these requirements. An elicitation procedure was developed and utilized with small groups of Army officers in a tactical role-playing exercise involving a specified Division-level scenario. Information requirements in the form of tactical questions were generated and reviewed by participants, both individually and together. In addition, for each question, the participants completed a form which provided descriptive information such as whether the answer to the question is available from a display with conventional symbology (FM 21-30). In an effort to organize the information requirements, an hierarchical clustering technique was applied that analyzed the similarity between questions in terms of 58 semantic features (e.g., friendly, enemy, artillery, vulnerability, etc.).

The elicitation sessions resulted in the generation of a total of 272 distinct tactical questions. These questions formed seven major clusters which were assigned the following names to reflect the central theme of their respective information content: friendly, enemy, time/capability, status, activities/procedures, terrain/routes, and planning. The descriptive data about the questions, analyzed for each cluster of information individually and for the entire set of questions, indicated that conventional symbology fails in many respects to meet basic user needs. For example, 43% of the information requirements identified were said to be unavailable from a conventional display. Furthermore, there appears to be a proliferation of personalized techniques being employed by users to portray their information requirements. Some major informational deficiencies in conventional symbology are identified, and examples are given on how the findings can be employed in development efforts toward making standardized, tactical symbology more useful and effective.

141 Learner, D. B., & Alluisi, E. A. (1956). Comparison of four methods of encoding elevation information with complex line-inclination symbols (WADC-TN-56-485). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-110 547)

The use of a one- or two-line inclination code has been found, in previous experiments conducted under this contract, to be an effective method for encoding from 10 to about 32 possible categories of information. For some purposes, however, a much larger alphabet of symbols is required. This study was a preliminary investigation of the psychological feasibility of employing coding schemes based on complex line-inclination symbols for encoding information, such as elevation, that may require as many as 50 unique symbol categories.

Four groups of 20 subjects each decoded elevation information that had been encoded by the use of four different coding ensembles. Each group worked with a different one of the four codes. The four ensembles were called the binary, the decimal, the wheel, and the clock codes. The first three of these were based on the same type of stimulus symbol (eight lines radiating at 45-deg. angular separations from a central hub), whereas the clock code was based on a stimulus symbol consisting of a circle and two lines each of which could be discretely positioned to correspond to the hour positions of a clock.

The decimal and clock codes were decoded with greater speed than the wheel and binary codes. The wheel code was inferior to the other three codes with regard to accuracy. These data are regarded as another demonstration of S-R compatibility effects, and of the importance of considering both the alphabet and the readout in selecting an S-R ensemble for encoding any specific type of information.

The present results were obtained with subjects who had undergone less than one hour of practice in reading the specific code used by their group, but with displays that were oriented in fixed positions relative to the subjects. Although the two best of the four codes employed should undergo further study before being used for encoding elevation information, the data of this study indicate that they are psychologically feasible for such use.

142 Lerner, N. D., & Collins, B. L. (1980). The assessment of safety symbol understandability by different testing methods (NBSIR 80-2088). Washington, DC: National Bureau of Standards. (PB 81-185647)

This paper reports an experiment on the understandability of pictorial symbols proposed for fire-safety alerting. The experiment was designed to determine the understandability of specific symbols and to assess the effects of variations in both presentation and response methods.

The symbols were presented as slides, booklets, or placards. Subjects indicated their understanding of each symbol's meaning either by writing down a brief definition or by selecting the correct answer from among four alternatives. For both methods, subjects rated their confidence in the correctness of the answers. In the second phase of the experiment, subjects were given fifteen different messages, and asked to draw a symbol for each idea.

Mode of symbol presentation had no effect on understandability, while the use of definition and multiple choice procedures led to generally similar conclusions. The confidence ratings provided additional information about discrepancies between the two response methods.

The understandability of the 25 symbols ranged from near zero to virtually total comprehension. These data underscore the need to determine the understandability of safety symbols prior to standardizing a symbol set.

143 Lockhead, G. R. (1972). Processing dimensional stimuli: A note. Psychological Review, 79, 410-419.

Analysis of available data shows that the nature of stimulus combinations, the particular stimulus dimensions used, affects how stimuli are perceived. Theories of stimulus processing, for example, serial or parallel, depend on how stimuli are perceived and thus depend on stimulus combinations. The data cannot be accounted for by any such singular processing model suggested to date. An alternative mode of processing which is in agreement with the data is proposed. The hypothesis suggests that a stimulus is first processed holistically, as a blob, which is defined. Subsequent processing of the blob into its components, or combinations of judgments of two or more blobs, occurs in a subsequent stage if the task requires. For object identification tasks, no later stages of processing are required.

144 Mackett-Stout, J., & Dewar, R. (1981). Evaluation of symbolic public information signs. Human Factors, 23, 139-151.

In a series of four experiments, symbolic representations of eight public information messages were evaluated in an attempt to identify the relative adequacy of each symbol. Four versions of each message were examined using measures of legibility distance, comprehension, preference, and glance legibility. Significant positive correlations were found among the first three measures. An efficiency index was employed as an overall measure of the effectiveness of individual symbols, and recommendations were made concerning their future use.

145 Maddox, M. E., Burnette, J. T., & Gutmann, J. C. (1977). Font comparisons for 5 x 7 dot matrix characters. Human Factors, 19, 89-93.

Two newly designed fonts and the Lincoln/Mitre font are compared for legibility using tachistoscopic presentation and forced identification. All three fonts were constructed with a matrix of 5 x 7 dots and were presented with a computer-generated display. The results were analyzed parametrically in terms of total

identification errors and by conventional confusion matrices. The analysis showed significantly fewer errors with the font utilizing the largest number of dots per symbol than with either of the other two fonts. The confusion matrices revealed that the most severe confusions occur for different characters in different fonts.

(From Human Factors, 1977, 19, pp. 89-93. Copyright 1977 by the Human Factors Society, Inc. Reprinted by permission.)

146 Martin, M. (1979). Local and global processing: The role of sparsity. Memory & Cognition, 7, 476-484.

It has recently been proposed that global processing precedes local processing of a visual scene even when the local and the global aspects are similar in nature (e.g., both alphabetic). The two types of processing were compared here in four different ways, for stimuli with many and with few local elements (i.e., differing sparsities). These methods consisted of assessing naming latency, intrastimulus Stroop-like interference, intermodality Stroop-like interference, and phenomenal judgment. The results of four experiments were consistent in demonstrating global processing priority for many-element stimuli but local processing priority for few-element stimuli.

(From Memory & Cognition, 1979, 7, pp. 476-484. Reprinted by permission of Psychonomic Society, Inc.)

147 McCallum, M. C., & Rogers, S. P. (1982). Application of coding methods in development of symbology for a computer generated topographic display used by Army aviators (Technical Report 459-2). Santa Barbara, CA: Anacapa Sciences, Inc.

This report presents the results of a literature review conducted to identify previous research that could provide guidelines during the initial design of a new symbol system for topographic and tactical data display. Methods of symbol design based on ten dimensions of visual coding--shape, alphanumeric, size, numerosity, inclination, brightness, color, flash rate, stereo depth, and apparent movement--are identified and evaluated. The evaluation of alternative coding methods is based on three design-oriented criteria: amount of information conveyed, types of data coded, and aid to operator visual search. These criteria are considered in the review of research investigating both unidimensional and more complex multidimensional symbol systems. A model is presented which identifies the relationships between many factors and symbology system characteristics that ultimately affect the design of symbol systems.

148 McCann, C. (1979). Legibility of military symbols on a cathode ray tube (DCIEM-79-R-38). Ontario, Canada: Defence and Civil Institute of Environmental Medicine. (DTIC No. AD-A078 649)

The legibility of selected military map symbols on a CRT display was determined by testing a symbol set of nineteen primary role descriptors symbols for military units using a tachistoscopic presentation technique. Simpler geometric symbols composed of fewer line components were more quickly recognized than complex ones, and were also the source of fewer errors. Symbols with circular or curved components were more likely to be confused with each other than with symbols composed of linear components.

149 Miller, J. W. (1981). Global precedence: Information availability or use? Reply to Navon. Journal of Experimental Psychology: Human Perception and Performance, 7, 1183-1185.

In response to Navon's comments, I elaborate upon the distinction between processes that make information available and processes that use information, and I clarify the argument that global precedence results from the latter kinds of processes. This argument does not depend on the assumption that slow processes have no influence on responses. The question of what terms are appropriate for discussing the intended distinction is also considered.

150 Morin, R. E., Forrin, B., & Archer, W. (1961). Information processing behavior: The role of irrelevant stimulus information. Journal of Experimental Psychology, 61, 89-96.

The present experiment was designed to investigate the effects of irrelevant stimulus information upon information processing behavior in a disjunctive reaction time (RT) task. Ten *S*s were assigned to each of five conditions defined by the number of equi-probable stimulus events presented and by the number of correct response alternatives available. In three conditions the amount of stimulus information (0, 1, or 2 bits) and the amount of response information were equated. In two conditions stimulus uncertainty (2 bits) exceeded response uncertainty (1 bit). Though identical with respect to information measures the latter conditions differed in terms of the perceptual demands placed upon *S*.

The presence of irrelevant stimulus information did not significantly influence the rate of information processing at advanced levels of performance. This result was found to hold when (*a*) both relevant and irrelevant stimulus dimensions were presented to the same modality and in spatio-temporal contiguity, and (*b*) the character of the discrimination task required that *S* attend to all salient features of the stimulus display. On the basis of these findings it was suggested that the linear relation between stimulus information and RT observed by Hyman, and replicated in the present study, can be attributed to the confounding of stimulus, response, and transmitted information. In addition, the data provided some support for Bricker's contention that the rate of information processing is more closely associated with the amount of information transmitted than with response uncertainty.

151 Morrison, J. L. (1974). A theoretical framework for cartographic generalization with emphasis on the process of symbolization. International Yearbook of Cartography, 14, 120-127.

The article develops a theoretical framework for generating topographical symbology. It contends that once the formal aspects of a process are outlined, that cartographers must establish standardized schemes for the creation as well as the interpretation of topographical map symbology. Given this, it is believed that cartographers can move toward a common cartographic language.

152 Morrison, T. R. (1984). Perceptual and cognitive considerations in symbology design. Doctoral dissertation. Vermillion: University of South Dakota.

Extensive literature exists on the effects of various methods of coding visual information. This literature has primarily addressed sensory factors and number of discriminable levels for coding along each dimension. The present study consisted of two experiments which investigated various coding schemes with respect to imposed memory loads. The Cockpit Display of Traffic Information (CDTI) provided the real-world display task for which two experiments were designed and conducted in such a manner that an interpretation was possible within the theoretical context of the item-recognition literature.

The results from Experiment I suggest that, within the CDTI task situation, humans employ a memory scanning operation other than serial. The results of Experiment II provide strong support for significant improvements in CDTI performance as a function of designing display symbology which reduces memory load imposed on the operator. The results indicate that non-numeric codes allowed for parallel processing, while the numeric codes required serial processing. Certain achromatic codes achieved the same performance gains as color.

153 Moses, F. L., & Vande Hei, R. P. (1978). A computer graphic-based aid for analyzing tactical sightings of enemy forces (Technical Report 287). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A049 578)

Computer and computer-driven graphics are being explored for potential utilization by the battlefield staff. One such effort is designed to assist in detecting patterns by replacing manual plots of sightings with efficient and flexible computer graphic techniques and associated algorithms. An interaction of the analyst with these displays and algorithms for analyzing sightings forms the basis for the present evaluation of a battlefield interpretation aid.

Questions were asked about direction, speed of movement, and changes in location of battlefield activity in a classical division attack scenario. Six aided participants derived answers by specifying activity on a graphic display from which the computer calculated distances, speeds, etc. Six unaided participants derived answers from the displays without the use of computerized calculations. Responses in the aided condition were substantially more accurate than responses

in the unaided condition. Measures of time did not meaningfully discriminate between the conditions. Accuracy results suggest that analyst-controlled computerized algorithms should be used for determining enemy patterns for computer graphic displays of sightings. The aid could be improved by better adaptation to equipment, thorough training and design refinements. However, results are sufficiently promising to suggest provision for accommodating mass/movement and related temporal/spatial analysis algorithms in requirements documents.

154 Mudd, S. A., & Karsh, R. (1961). Design of a picture language to identify vehicle controls: I. General method. II. Investigation of population stereotypes (Technical Memorandum 22-61). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-272 263)

A general approach to the problem of developing a picture language or set of picture-symbols, as labels for equipment controls, is discussed. Negative and positive arguments for such a system of symbols and possible research strategies are considered. The results of the first of a series of studies are reported. United States and foreign military personnel were asked to make line drawings that might convey the meaning of various wheeled-vehicle controls. These drawings were subjected to a qualitative analysis to extract common design elements. A preliminary set of 34 symbols, based on the resultant design elements, is presented. Recommendations for further research are included.

155 Muller, P. F., Jr., Sidorsky, R. C., Slevinske, A. J., Alluisi, E. A., & Fitts, P. M. (1955). The symbolic coding of information on cathode ray tubes and similar displays (WADC TR-55-375). Wright-Patterson Air Force Base, OH: Wright Air Development Center. (DTIC No. AD-103 239)

This report summarizes the results of a series of eleven studies of the feasibility of several different types of symbols for the coding of information on cathode ray tubes (CRT) and similar displays for use in future air traffic control and related systems. Although research is still in progress on some of the problems of symbolic coding, the results to date are sufficiently definitive to warrant recommendations for certain specific engineering applications.

The report is divided into two sections. Section I contains specifications and recommendations for engineering applications to CRT-type displays. Section II contains the detailed results of the laboratory investigations, on which the recommendations of Section I are based. Section I is intended primarily for use by engineers; Section II will be of interest primarily to research psychologists.

The report deals first with four basic code symbols (inclination, ellipse ratio, blip diameter, and color), and then with some of the numerous possibilities for constructing multi-dimensional alphabets by combining two or more of the basic code symbols. With the exception of color, all of these codes are presently feasible for use with an electrostatic-type CRT display. They are all feasible with an optical projection system.

Inclination is the most promising of the four code symbols investigated. Twelve, and if necessary as many as sixteen, categories of inclination can be employed, even when a small amount of noise is expected on the display. By employing a complex symbol consisting of a central blip plus more than one radius line, inclination can be made the basis for a complex-symbol alphabet providing up to twelve bits of information per symbol.

156 Navon, D. (1977). Forest before trees: The precedence of global features in *visual perception*. Cognitive Psychology, 9, 353-383.

The idea that global structuring of a visual scene precedes analysis of local features is suggested, discussed, and tested. In the first two experiments subjects were asked to respond to an auditorily presented name of a letter while looking at a visual stimulus that consisted of a large character (the global level) made out of small characters (the local level). The subjects' auditory discrimination responses were subject to interference only by the global level and not by the local one. In Experiment 3 subjects were presented with large characters made out of small ones, and they had to recognize either just the large characters or just the small ones. Whereas the identity of the small characters had no effect on recognition of the large ones, global cues which conflicted with the local ones did inhibit the responses to the local level. In Experiment 4 subjects were asked to judge whether pairs of simple patterns of geometrical forms which were presented for a brief duration were the same or different. The patterns within a pair could differ either at the global or at the local level. It was found that global differences were detected more often than local differences.

157 Navon, D., & Norman, J. (1983). Does global precedence really depend on visual angle? Journal of Experimental Psychology: Human Perception and Performance, 9, 955-965.

Global advantage has been found in some studies to hold only in stimuli subtending no more than 7o-10o of visual angle. We argue that those studies confounded globality and eccentricity. To avoid this confound we used stimuli with all their elements located along their perimeter (e.g., Cs and circles). These were presented in two visual angle conditions, small (2o) and large (17.25o). In Experiment 1 subjects had to indicate either the direction of an opening of a C made up of circles or of Cs that were the elements of a circle. Contrary to previous findings, global advantage was found for both large and small visual angle conditions. Results from a control condition seem to indicate that the major determinant of that global advantage was relative size. In Experiment 2 subjects responded to the global or local levels of right- or left-facing Cs made up of right- or left-facing Cs. For the small visual angle condition, the global level interfered with processing of the local level, but not vice versa. For the large visual angle, however, interference effects were smaller and symmetrical, even though a sizeable difference in mean reaction time

was observed between the responses to the local and global levels. It is suggested that the time it takes to respond to a level when relevant and the level's effectiveness as a distractor when irrelevant are determined at two different stages of processing.

158 Nawrocki, L. N. (1972). Alpha-numeric versus graphic displays in a problem-solving task (Technical Research Note 227). Arlington, VA: U.S. Army Behavior and Systems Research Laboratory. (DTIC No. AD-748 799)

To assist commanders in making tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and displayed in the most efficient manner possible. To meet this need, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. At the same time, a requirement exists for research to determine how human abilities can be utilized to achieve the optimal functional effectiveness of information processing systems. BESRL's MANNED SYSTEMS research effort in this area is concerned with enhancement of human performance and facilitation of man-machine interaction in relation to total system effectiveness. Experimentation findings have implications for systems design, development, and operational use.

The experiment reported on here was designed to determine how alpha-numeric and graphic presentation affect performance, in terms of speed and accuracy, under two sets of system requirements: 1) need to base a decision on memory of information previously displayed versus no memory requirement, and 2) complexity of information to be held in memory (memory load).

Results of this study, in conjunction with previous comparative evaluation of the two alternative display modes, suggest that under a variety of tasks and conditions, there is no clear-cut advantage to the use of either a alpha-numeric or graphic displays when memory of displayed material was required. Hence, the choice of display type may be primarily one of cost consideration if time and accuracy are the primary determinants of system performance. However, when memory was not required, alpha-numeric displays resulted in fewer errors of omission than did graphic displays. It was also found that increasing complexity caused a deterioration in speed when no memory was required and a decrement in accuracy when memory was required. In further research, the relationship between type of errors produced and display mode will be examined more closely, especially in tasks where spatial manipulation of items of information is involved.

159 Neisser, U., Novick, R., & Lazar, R. (1963). Searching for ten targets simultaneously. Perceptual and Motor Skills, 17, 955-961.

*S*s were given extensive practice in scanning through lists of printed symbols for particular targets. By the thirteenth day, they scanned as rapidly when searching for any of 10 different targets as when searching for any of five, or

for one target alone. These results are compatible with the assumption that many subsystems for processing visual information can operate in parallel, at least in situations where a high degree of accuracy is not required.

(From Perceptual and Motor Skills, 1963, 17, pp. 955-961. Copyright 1963 by Southern Universities Press.)

160 Newman, K. M., & Davis, A. K. (1961). Multidimensional nonredundant encoding of visual symbolic display (TR 1048). San Diego, CA: Navy Electronic Laboratory. (DTIC No. AD-714 847)

Determine whether a nonredundant means of encoding information for visual displays could be derived from several encoding dimensions. Compare the effectiveness of geometric-only encoding with geometric-plus-brightness level, flashing rate, and color encoding, with respect to speed and accuracy in the performance of two different tasks. The results were as follows:

1. The encoding variables tested differ significantly from each other in both the localization and the decoding tasks.

2. Nonredundant use of two and three different colors improves both speed and accuracy significantly, especially speed.

3. The combination of several levels of three different encoding dimensions is detrimental to performance irrespective of the task, particularly when three flashing rates are included.

4. The results of the study also emphasize clearly the important difference known to exist between a perceptual and a learning task.

161 Palmer, S. E. (1977). Hierarchical structure in perceptual representation. Cognitive Psychology, 9, 441-474.

A theoretical framework for perceptual representation is presented which proposes that information is coded in hierarchical networks of nonverbal propositions. The hierarchical structure of the representations implies selective organization: Some subsets of a figure will be encoded as integral, structural units of that figure, while others will not. A context-sensitive metric for the "goodness" of a part within a figure is developed, corresponding to the probability that the subset will be encoded as a structural unit. Converging evidence supporting this position is presented from four different tasks using simple, straight-line figures. The tasks studied are (a) dividing figures into "natural" parts, (b) rating the "goodness" of parts within figures, (c) timed verification of parts within figures, and (d) timed mental synthesis of spatially separated parts into unitary figures. The results are discussed in terms of the proposed theory of

representation, the processes that operate on those representations, and the general implications of the data for perceptual theories.

(From Cognitive Psychology, 1977, 9, pp. 441-474. Copyright 1977 by Academic Press, Inc.)

162 Palmer, S. E. (1978). Structural aspects of visual similarity. Memory & Cognition, 6, 91-97.

The hypothesis that visual representations for lines and/or points are independent structural units was tested using similarity judgment and speeded discrimination for pairs of six-segment letter-like figures. The stimuli were constructed such that each of two comparison figures had five segments in common with a standard figure. One figure was similar to the standard in its higher order structure (connectedness and closedness properties), whereas the other differed. The results show that the figures with similar higher order structure were systematically judged more similar to the standard than the figures with different structure. The former were also more difficult to discriminate from standards than the latter, as indicated by both time and error measurements. These effects were less pronounced in sequential than in simultaneous comparisons.

(From Memory & Cognition, 1978, 6, pp. 91-97. Reprinted by permission of Psychonomic Society, Inc.)

163 Pearson, W. H., Rundle, M. H., & Hoffman, M. S. (1979). Studies in tactical symbology. I. Preferred tactical symbology for Joint Tactical Information Distribution System (JTIDS) (AMRL-TR-78-115). Wright-Patterson Air Force Base, OH: Aerospace Medical Research Laboratory. (DTIC No. AD-A070 706)

This report describes one of a series of studies attempting to design an optimal symbol set to use in tactical order-of-battle display for single seat aircraft. Air Force tactical pilots flying F-111D's and F-15's were interviewed to ascertain their preferences for symbols to represent 42 tactical objects or events. Model or typical symbol constructions for each object/event for both types of pilots were selected, tabled, and compared with choices of naive college students and a panel of Air Force professional human factors personnel. Pilots scored significantly higher than students on a set of spatial perception tests, were more consistent among themselves in type of symbol constructed, and remembered their symbols better; these stereotypical pilot responses presumably reflect the effect of their flight training and experience. Conclusions were: (1) symbols should be as realistic or pictorial as possible, (2) existing standard symbols should be used, and (3) the symbol set should be standardized at the highest Air Force administrative level practicable. Pilot-in-the-loop mission based simulations are to be developed in which tactical display symbology will be evaluated based on the findings of this study.

164 Pearson, W. H., & Shew, R. L. (1980). Studies in tactical symbology. II. Symbol meaningfulness and learning efficiency (AFAMRL-TR-80-115). Wright-Patterson Air Force Base, OH: Air Force Aerospace Medical Research Laboratory. (DTIC No. AD-A093 952)

A symbol association study was conducted to select from among three symbol sets a "best" set to convey tactical order-of-battle information on a CRT display to a pilot of a single-seat fighter aircraft. The three symbol sets were: (1) a set recommended by a panel of Air Force experts (SSC), (2) a set of pictorial symbols resembling the objects they were to represent, and (3) a set of geometric symbols with alphanumeric modifiers. The latter two symbol sets were composites based on symbols constructed by Air Force tactical pilots in an earlier experiment. The criteria used to select the "best" symbols were: (1) fewest trials and least time to learn; (2) fastest recognition time for meaning; and (3) ease of display, i.e., fewest number of lines to generate the symbol. Each symbol set was viewed by ten separate college students with some military experience. After each symbol was presented, the subject picked its meaning from a list on a graphic display device driven by an IBM 370/155 computer which controlled the symbol presentation and calculated learning scores, i.e., recall times, trials to learn, etc. On the basis of the first two criteria, symbols from the pictorial set were selected for aircraft and naval vessels and objects/events pertaining to them. The remainder of the symbols were selected on the basis of ease of display and originated about equally from all sets.

165 Pomerantz, J. R., & Garner, W. R. (1973). Stimulus configuration in selective attention tasks. Perception & Psychophysics, 14, 565-569.

The possibility that perceptual configuration of stimulus elements impairs the ability to attend selectively to individual elements was tested with two-element stimuli, constructed by placing two curved lines in close proximity. Ss rapidly classified series of these stimuli which could differ on both elements or on only one with the second held constant. It was hypothesized that if the two elements formed a configuration, then Ss should have difficulty attending selectively to the element relevant for classification while filtering information from the other element. This result was obtained in one experiment with both stimulus elements oriented vertically, and it is concluded that these stimuli were perceived as unanalyzed, nominally related shapes. In another experiment, with one stimulus element oriented horizontally, selective attention to the relevant element was possible.

166 Pomerantz, J. R., Sager, L. C., & Stoever, R. J. (1977). Perception of wholes and of their component parts: Some configural superiority effects. Journal of Experimental Psychology: Human Perception and Performance, 3, 422-435.

Theories of visual pattern recognition frequently assume that processing begins with an analysis of the pattern into component parts, which are often assumed to be line segments of particular orientations, lengths, position, and curvatures. The present experiments measured discriminability of these simple parts when presented either in isolation or within configural contexts that provided no formal information useful for the discrimination. Certain contexts either impaired or did not affect performance. Other contexts were found, however, which dramatically improved discriminability. Thus, two patterns which differed only in a single part could be discriminated from each other more quickly than could their distinguishing parts shown in isolation. Further experiments suggest that this "configural superiority" effect influences perceptual components of processing rather than memorial components. The mechanism underlying configural superiority appears to be the detection of novel and distinguishing features, such as corners and intersections, which emerge when parts are placed in close proximity to each other. The outlines of a model for preattentive feature discrimination are presented.

167 Pomerantz, J. R., & Schwaitzberg, S. D. (1975). Grouping by proximity: Selective attention measures. Perception & Psychophysics, 18, 355-361.

The role of element proximity in perceptual grouping was examined in tasks requiring speeded discrimination of two-element visual patterns. Grouping of two elements was defined as the failure of attention to be focused on one element selectively in filtering tasks where only that one element was relevant to the discrimination. Failure of selective attention was measured by the degree of interference caused by variation of the irrelevant element. Grouping was shown to diminish monotonically as the spacing between two elements was increased. At a given spacing, grouping could be reduced or eliminated by the introduction of a third element into the stimulus field, presumably because the addition of this element triggered a reorganization of the perceptual field into a new grouping structure. Grouping appeared to facilitate performance on condensation tasks requiring distributed attention, to the degree that the condensation tasks were actually easier than the filtering tasks at close proximities. Paradoxically, for some tasks, moving an irrelevant element away from a relevant one actually impaired performance, suggesting that paying attention to irrelevant information could be beneficial. This result, if generalizable, suggests that grouping be conceptualized not as an automatic process under preattentive control but as an optional process under strategic control.

168 Pond, D. J. (1988). Military symbologies: An overview and select annotated bibliography (Technical Note 6-88). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

This report discusses critical symbology issues and areas of symbology research considered to merit additional inquiry. Variables that could impact symbol effectiveness are categorized and discussed as personnel (e.g., soldier experience), operational (e.g., combat stress), and technological (e.g., display type) influences.

Three themes emerged from this review. First, across all agencies, operations, and systems, there is a recognized need for improved symbologies in order to maintain or enhance efficiency under increasingly difficult operational conditions. Second, there is a general, if ill-defined, call for some degree of symbology standardization. Third, one or more aspects of a traditional "systems approach" to design are frequently considered crucial elements of the operational system for which a symbol set is being developed.

Finally, two actions appear essential in charting an efficient and meaningful course for symbology research. First, an assessment must be made of the current status of all symbology research programs regarding mission, approaches, problems, and plans. Second, a mechanism must be created to assure the continued exchange of up-to-date information among members of the symbology research community.

169 Posner, M. I., & Mitchell, R. F. (1967). Chronometric analysis of classification. Psychological Review, 74, 392-409.

This series of studies represents an effort to extend the subtractive method of Donders to the analysis of depth of processing in simple classification tasks. The stimuli are always pairs of items (letters, nonsense forms, digits) to which S must respond "same" or "different" as quickly as possible. Levels of instruction are physical identity (e.g., AA), name identity (e.g., Aa), and rule identity (e.g., both vowels). By use of the subtractive method, times for matches at each level are analyzed. The emphasis is not placed upon the times themselves but upon their relevance for understanding the operations and mechanisms involved in perceptual matching, naming, and classifying.

170 Potash, L. M. (1977). Design of maps and map-related research. Human Factors, 19, 139-150.

Three characteristics of hardcopy maps, scale, interrelatedness of symbols, and standardized symbology, are reviewed. Their implications for future map-related research and design are discussed. Research on types of coding used in visual

displays is discussed in terms of its applicability to hardcopy maps. Specific suggestions for hardcopy map design are based on the literature comparing different kinds of map products.

(From Human Factors, 1977, 19, pp. 139-150. Copyright 1977 by the Human Factors Society, Inc. Reprinted by permission.)

171 Rappaport, M. (1957). The role of redundancy in the discrimination of visual forms. Journal of Experimental Psychology, 53, 3-10.

Four experiments were performed to determine the effect of two types and five levels of redundancy on *Ss'* ability to recognize visual patterns under two conditions of visual noise. When background noise was present redundancy was found to facilitate rapid discrimination; when stimulus noise was absent an increase in redundancy was associated with an increase in recognition times. The longer times in the noise-free case appeared to be attributable primarily to the difficulty of discriminating smaller details in the figures which were more redundant.

No differences in sorting times were found for figures with two different types of redundancy presented in the noise-free situation. The lack of differences was interpreted as due, in part, to the nonutilization of redundant features of a stimulus by *S* when external noise was absent.

It was suggested that in certain situations there may exist a balance of effects between the beneficial characteristics of various types of redundancy and the detrimental features that arise when redundancy is introduced in too great amounts or in an ineffective way. Implications of the present approach for an interpretation of two traditional Gestalt figural concepts were mentioned.

172 Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 81, 275-280.

The present study evaluates a class of models of human information processing made popular by Broadbent. A brief tachistoscopic display of one or two single letters, four-letter common words, or four-letter nonwords was immediately followed by a masking field along with two single-letter response alternatives chosen so as to minimize informational differences among the tasks. Giving *Ss* response alternatives before the stimulus display as well as after it caused an impairment of performance. Performance on single words was clearly better than performance on single letters. The data suggest that the first stages of information processing are done in parallel, but scanning of the resultant highly processed information is done serially.

173 Remington, R., & Williams, D. (1986). On the selection and evaluation of visual display symbology: Factors influencing search and identification times. Human Factors, 28, 407-420.

Three single-target visual search tasks were used to evaluate a set of cathode-ray tube (CRT) symbols for a helicopter situation display. The search tasks were representative of the information extraction required in practice, and reaction time was used to measure the efficiency with which symbols could be located and identified. Familiar numeric symbols were responded to more quickly than graphic symbols. The addition of modifier symbols, such as a nearby flashing dot or surrounding square, had a greater disruptive effect on the graphic symbols than did the numeric characters. The results suggest that a symbol set is, in some respects, like a list that must be learned. Factors that affect the time to identify items in a memory task, such as familiarity and visual discriminability, also affect the time to identify symbols. This analogy has broad implications for the design of symbol sets. An attempt was made to model information access with this class of display.

174 Saenz, N. E., & Riche, C. V., Jr. (1974). Shape and color as dimensions of a visual redundant code. Human Factors, 16, 308-313.

Studies have been conducted which indicate that redundant coding is effective in facilitating the locating of a target among other objects. This study examines that hypothesis for a range of the shape and color variables. All possible combinations of four shapes and four colors were used as targets in the experiment. The times to locate six each of the targets among 36 background objects for 16 displays in each of three coding conditions of the experiment were determined for 24 subjects. The targets could be differentiated from the background objects on the basis of color only, shape only, and redundant color/shape. The results indicate a difference among the coding conditions, the colors, and the shapes, and in the code-by-shape and code-by-color interactions. An important finding is that the redundant code and the color code conditions did not differ. The data are examined for possible explanations of this result and some implications are suggested.

175 Samet, M. G. (1975). Quantitative interpretation of two qualitative scales used to rate military intelligence. Human Factors, 17, 192-202.

Thirty-seven intelligence officers completed two replications of tasks designed to investigate their subjective, quantitative interpretations of the source reliability and information accuracy (plausibility) rating scales. In judging a report, subjects were influenced much more by the accuracy rating of the report's

content than by the reliability rating of the report's source. The mean probabilities assigned to the truth likelihood of reports described a linear relationship between rating level and probability for each scale. Most subjects were unable to treat reliability and accuracy independently; for these subjects, the higher a report's reliability rating, the higher the accuracy rating expected, and vice versa. Subjects were relatively consistent in their interpretations, but marked differences between subjects were observed. Structural inadequacies of the scales are pointed out and the development of a single-dimensional, quantitative scale is recommended.

176 Samet, M. G. (1983). Development of innovative graphic symbology for aiding tactical decision making (Technical Report PFR-1103-83-10). Woodland Hills, CA: Perceptronics, Inc. (DTIC No. AD-A135 119)

The goals and accomplishments of a program of research and development directed at the systematic design, implementation, and evaluation of graphic concepts for supporting tactical decision making are summarized. These aids focus on new ways to dynamically portray and adaptively manipulate tactical symbols on computer-generated displays so that relevant task-based performance can be enhanced. A new form of automated situation-display system that efficiently and effectively served the information requirements and processing demands of tactical users was demonstrated.

177 Samet, M. G., Geiselman, R. E., & Landee, B. M. (1980). An experimental evaluation of tactical symbol-design features (Technical Report 498). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A115 895)

Sixteen non-military participants learned each of two symbol sets (conventional, iconic) to a criterion. Each set contained three basic symbols representing unit types of armor, mechanized infantry, and infantry. After learning a symbol set, each participant was shown a series of situation displays, where some displays contained symbols coded with either perimeter-density or vector projection to convey supplementary unit-attribute information (unit strength or firepower reach) needed for typical tactical tasks. For each display, the participant was asked questions corresponding to different behavioral processes (identification, search, comparison, pattern recognition). Overall, the results suggested that iconic symbols may not necessarily be preferable to conventional symbols in certain situations; and, although the portrayal of supplemental unit information can slow some aspects of information processing, certain symbol-design features appear to create less interference than others. Specifically, (a) iconic symbols did not yield faster identification performance than conventional symbols, and conventional symbols yielded faster pattern-recognition performance than iconic symbols; (b) the portrayal of supplemental unit attributes slowed processing of unit-type information in all four tasks, but vector projection created less interference than perimeter density in three of four tasks; (c) unit-strength

information was processed faster when it was portrayed as perimeter density, and fire-power reach information was processed faster when portrayed as a vector projection. In a supplementary task which required integration of information from several symbols into an analytical judgment (threat value assessment), performance accuracy was found to be insensitive to the conventional versus iconic symbology comparison. The results were discussed in terms of the complexity of the implications involved in the selection of symbol design features and their correspondence with tactical concepts.

178 Samet, M. G., Geiselman, R. E., & Landee, B. M. (1982). A human performance evaluation of graphic symbol-design features. Perceptual and Motor Skills, 54, 1303-1310.

Sixteen subjects learned each of two tactical display symbol sets (conventional symbols and iconic symbols) in turn and were then shown a series of graphic displays containing various symbol configurations. For each display, the subject was asked questions corresponding to different behavioral processes relating to symbol use (identification, search, comparison pattern recognition). The results indicated that: (a) conventional symbols yielded faster pattern-recognition performance than iconic symbols, and iconic symbols did not yield faster identification than conventional symbols, and (b) the portrayal of additional feature information (through the use of perimeter density or vector project coding) slowed processing of the core symbol information in four tasks, but certain symbol-design features created less perceptual interference and had greater correspondence with the portrayal of specific tactical concepts than others. The results were discussed in terms of the complexities involved in the selection of symbol design features for use in graphic tactical displays.

179 Sarli, G. G., & Carter, R. J. (1983). Geometric radar symbology: Static cathode ray tube testing. Proceedings of the 24th Annual Conference of the Military Testing Association (AFHRL-TP-83-16), 605-610. (DTIC No. AD-A126 554)

Many air defense (AD) systems use geometric symbols to indicate aircraft on system displays and different shapes to encode friend-or-foe information. The purpose of ARI's AD symbology research was to identify sets of geometric symbols associated with high discriminability and quick response times. This paper deals with Phase 3, in which the symbol sets were presented upon a cathode ray tube (CRT) display. Symbol shape was the independent variable; RT and errors were the dependent variables. The hypotheses were that some sets would have lower RTs and errors, and that the results of Phases 2 and 3 would agree.

180 Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review, 84, 1-54.

A two-process theory of human information processing is proposed and applied to detection, search, and attention phenomena. Automatic processing is activation of a learned sequence of elements in long-term memory that is initiated by appropriate inputs and then proceeds automatically--without subject control, without stressing the capacity limitations of the system, and without necessarily demanding attention. Controlled processing is a temporary activation of a sequence of elements that can be set up quickly and easily but requires attention, is capacity-limited (usually serial in nature), and is controlled by the subject. A series of studies using both reaction time and accuracy measures is presented, which traces these concepts in the form of *automatic detection* and *controlled earch* through the areas of detection, search, and attention. Results in these areas are shown to arise from common mechanisms. Automatic detection is shown to develop following consistent mapping of stimuli to responses over trials. Controlled search is utilized in varied-mapping paradigms, and in our studies, it takes the form of serial, terminating search. The approach resolves a number of apparent conflicts in the literature.

181 Schutz, H. G. (1961). An evaluation of formats for graphic trend displays--Experiment II. Human Factors, 3, 99-107.

This study was designed to determine which of three types of trend formats results in superior performance for a task requiring the subject to make complex decisions. Three commonly used formats were included in the study: line type, vertical-bar type, and horizontal-bar type. Two secondary independent variables were: number of time points and amount of missing data. Results of the study indicate that preference should be given to line-type graphs, followed closely by the vertical-bar type. A secondary finding was that irrelevant points and missing data on graphic trend displays represent important factors in the degradation of operator performance.

182 Schutz, H. G. (1961). An evaluation of methods for presentation of graphic multiple trends--Experiment III. Human Factors, 3, 108-119.

The primary objective of this study was to determine the effect of multiple-line versus multiple-graph presentation of trend-type displays on operator performance. Four types of lines having low confusability were determined experimentally from a sample of twenty-five lines. The primary variable was single-graph, multiple-line presentation versus multiple-graph single-line presentation. Other variables included in this study were: number of lines, degree of confusion among lines, coding of lines, and two operator tasks: point-reading and comparing. It was found that for the point-reading task, either type of display is acceptable, but for the comparing task, the multiple-line display

is much superior to the multiple-graph display. Moreover, the use of color coding for the graph lines tended to improve performance slightly.

183 Semple, C. A., Jr., Heapy, R. J., Conway, E. J., Jr., & Burnette, K. T. (1971). Analysis of human factors data for electronic flight display systems (AFFDL-TR-70-174). Wright-Patterson Air Force Base, OH: Air Force Flight Dynamics Laboratory. (DTIC No. AD-884 770)

This report presents the results of a review of 1178 technical documents dealing with human factors considerations in electronic flight display systems. Design-oriented human factors data are presented for the following families of design considerations: display size, information coding, alphanumerics, scale legibility, visual acuity, display system resolution, flicker, contrast ratio requirements, and environmental variables including ambient illumination, vibration and acceleration. Quantitative, design-oriented functional relationships are emphasized. Research recommendations are made where existing data were found inadequate for design use. A model is presented for organizing the variables impacting upon human performance as a function of electronic flight display system design.

184 Shontz, W. D., Trumm, G. A., & Williams, L. G. (1971). Color coding for information location. Human Factors, 13, 237-246.

Visual search performance was investigated as a function of color-coded and uncoded information location, number of categories coded, number of objects per category, and background clutter. Thirty-three subjects searched 12 areas of modified sectional aeronautical charts for a total of 48 checkpoints. Identification of checkpoints was established with labels plus geographical context information. Color served as a partially redundant code for information location. In general, the findings indicate that color coding for information location is most effective when: (1) many categories of information car or must be coded, (2) colors highly discriminable in peripheral vision are used, and (3) the number of objects per category is kept reasonably small.

185 Sidorsky, R. C. (1976). Color coding in tactical displays: Help or hindrance? Unpublished research report. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

The purpose of this research was to determine the effectiveness of color coding as a means for making tactical displays easier and faster to analyze.

Four groups of analysts observed visual displays of symbolically encoded information depicting the type, status and disposition of friendly/enemy units on the battlefield. Each group used a different code format. The code formats differed with respect to the category of information conveyed by color coding.

The performance of all groups was measured on three tasks. The tasks differed with regard to their level of complexity, i.e., required the extraction of one, two or three categories of information from each symbol.

Analyses of Variance were performed on measures of speed and accuracy of information processing. The results indicate that color can be of substantial benefit in terms of reduced processing time and errors. Information portrayed by traditional shape coding requires as much as 75% more processing time and produces 200% to 800% more errors. However, color is of value only it if is used to encode information that is extracted at the first level of analysis. The establishment of a standardized sequence of colors for tactical symbology to portray the status or condition of tactically relevant objects or events is suggested.

186 Sidorsky, R. C., Gellman, L. H., & Moses, F. L. (1979). Survey of current developments in tactical symbology: Status and critical issues (Working Paper 79-03). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

The complexity of modern warfare and recent advances in information processing technology have highlighted the need for a more effective symbology to communicate information to the command staff at division and corp levels. To this point the Army Research Institute (ARI) conducted a structured survey of nine of the Army's research and development efforts related to symbology. This report presents the results of this survey which dealt with factors as mission, tasking and coordination of the agency as well as methodology, equipment, perceived current problems and future plans with regard to symbology. Three general problems in symbology briefly are discussed: the lack of an adequate definition of symbology; the lack of a symbology typology; the need for improved coordination. Finally, the report concludes with a structured and annotated list of 34 current research issues representing the core questions or problems currently being discussed or researched in the R&D community.

187 Sleight, R. B. (1952). The relative discriminability of several geometric forms. Journal of Experimental Psychology, 43, 324-329.

The *S*s were required to sort a number of geometric forms presented in a complex visual display. There were 21 kinds of figures with six of each kind.
1. Discriminability as measured by sorting time was approximately ten times faster for the first ranking than for the last ranking figure.

2. On the basis of significance of differences between mean sorting times, it was possible to identify four groups in any one of which the figures were

approximately equally discriminable. The most discriminable group was composed of the following forms: swastika, circle, crescent, airplane, cross, and star.

3. A high positive correlation was found between the ranking of figures according to sorting time and ranking based on *Ss'* order of selection of items according to their "attention-getting" value.

4. Of the six best figures in terms of speed of sorting time, only one or two might be considered "simple" in the sense that this term is used by Gestalt psychologists.

188 Smith, S. L. (1963). Color coding and visual separability in information displays. Journal of Applied Psychology, 47, 358-364.

Twelve experimental Ss performed both visual search and class counting tasks, viewing displays containing 20, 60, or 100 items. Each item consisted of a vector, letter, and 3-digit number grouped together, and was presented as white-on-black in some displays, or in 1 of 5 colors. The color code was redundant with the 5 class-designator letters that were used. Average search and counting time, and counting errors, increased with increasing display density (number of items). None of these measures varied significantly among the 5 different target classes (colors). Addition of the redundant color code resulted in an average time reduction of 65% in the visual search task and 69% in the counting task, with a reduction of 76% in counting errors.

189 Smith, S. L., & Goodwin, N. C. (1971). Blink coding for information display. Human Factors, 13, 283-290.

Ten men scanned cathode-ray-tube displays to search for designated target items. Search time increased with increasing display density, and was 50% faster when a 3-cps bl' . was imposed on items of the target class. The blinking of nontarget items was almost equally effective, indicating that blink can be used either as an inclusion or exclusion code. In comparison with steady, nonblinking displays, search time was not significantly different for displays in which all items blinked, or in which a random selection of items blinked. It is concluded that for visual search tasks of the kind reported here, there is no marked deleterious effect of blink coding on symbol legibility, and no marked interference attributable to irrelevant blink.

190 Smith, S. L., & Goodwin, N. C. (1972). Another look at blinking displays. Human Factors, 14, 345-347.

Twelve subjects scanned displayed prose passages to detect randomly inserted letter substitution errors. In comparison with steady displays, this check-

reading task was performed 10% more slowly but with equal accuracy when the displayed material blinked at a 3-Hz rate. Although the potential value of blink coding confirmed in previous research is not questioned, the reduction in readability of blinking displays demonstrated in the present study suggests that some precautions must be taken in the practical application of this display coding technique.

191 Smith, S. L., & Thomas, D. W. (1964). Color versus shape coding in information displays. Journal of Applied Psychology, 48, 137-146.

Eight Ss counted objects of a specified color or shape on displays of 20, 60, or 100 items. Counting time and errors increased with increasing display density. Counting based on a 5-valued color code was faster and more accurate than counting using any of 3 shape codes. Color counting was not affected by the particular shape code on which the colors were superimposed. Shape counting was somewhat faster and/or more accurate when color did not vary on the display, and vice versa. Differences in counting performance appeared among the 3 shape codes and among certain of the symbols within shape codes, and small differences were confirmed among the particular code colors used.

192 Soar, R. S. (1958). Numeral form as a variable in numeral visibility. Journal of Applied Psychology, 42, 158-162.

Starting from data showing which numerals are confused with which among the currently most visible set of experimentally developed numerals, three new sets were designed in which common elements were minimized, and unique elements emphasized. An additional set developed by another investigator was included, and all were compared with a set of the currently most visible numerals. Data were collected tachistoscopically, with 20 replications of the five experimental conditions. Analyses of variance and covariance were performed on the data, and six of the experimentally developed numerals were shown to be significantly more visible than the current standard.

A hypothesis generalizing the results is proposed, which presumes two important but partially opposed variables in visibility of numerals to be boldness of stroke and openness of white space within the figure.

193 Spiker, V. A., Rogers, S. P., & Cicinelli, J. (1984). Search time on a computer-generated topographic map as a function of symbol color and background color (Technical Report 459-7). Santa Barbara, CA: Anacapa Sciences, Inc.

A visual search experiment was conducted to evaluate the legibility of a set of colored symbols for use on a computerized terrain map. The colors and symbols

evaluated in this study were selected on the basis of previous project research conducted under contract No. DAAK-80-82-0089 to support the efforts of the Avionics R&D Activity (AVRADA) at Fort Monmouth, New Jersey. AVRADA is currently developing a computer-generated topographic display (CGTD) system to be used by Army aviators. The CGTD system is expected to solve existing problems with map handling, scale, and content. It should also substantially improve cartographic support, map-oriented computations, and aviator-map interactions. A primary focus of the present research has been to delineate an optimal method for visually presenting color-coded information on the CGTD.

The search task involved showing observers, on each trial, the symbols displayed in random locations on a multi-colored terrain map. The response time to indicate the presence or absence of a predesignated target symbol was recorded, and compared to times from a similar search task which used a solid grey field as the background. The major factors in the repeated measures design included target symbol color, either RED, WHITE, or YELLOW; presence or absence of the target symbol; and (for the map condition) the background color on which the target was placed--either BLUE, PINK, light AQUA, dark AQUA, or GREY. Symbols were displayed on a 13-inch Mitsubishi shadow mask CRT, and subtended 14 minutes of visual arc. A total of 15 color-normal subjects were tested, with an average age of 24 years.

Overall, the map's symbology and colors proved quite legible. Response times to the map averaged about 2 seconds, which is in line with the amount of time a helicopter navigator has to look at a paper map during low-level flight. Also, response times to the map were only slightly slower compared to the solid grey condition, indicating that the varying chromaticities and luminances of the map slowed symbol search by only a modest amount.

Regarding the effects of color on search, RED ana WHITE targets were located slightly faster than were YELLOW targets. The five target color/background color combinations associated with the fastest response times were: RED/GREY, WHITE/GREY, RED/PINK, YELLOW/L.AQUA, and WHITE/BLUE. The combinations that produced the slowest responding were: RED/L.AQUA, YELLOW/GREY, WHITE/D.AQUA, YELLOW/BLUE, and YELLOW/PINK.

194 Spiker, V. A., Rogers, S. P., & Cicinelli, J. (1985). Effects of adaptation luminance and background chromaticity on the time to locate and identify colored symbols on a computer-generated topographic display (Technical Report 459-9). Santa Barbara, CA: Anacapa Sciences, Inc.

This report describes the results of an experiment that examined the effects of adaptation luminance and background chromaticity on the time to locate and identify colored CRT symbols on a computer-generated topographic map. The task involved showing subjects, on each trial, a single symbol displayed in a random location on either a multicolored terrain map or a luminance-matched monochrome grey map. The subject's task was to name the symbol as quickly as possible using one of nine names learned during pretraining. Through irrelevant to the task, the symbol's chromaticity and luminance (chrominance) varied randomly over trials, as did the background chrominance on which the symbol was placed. In addition to map chromaticity, symbol chrominance, and background chrominance, a fourth factor investigated in the study was adaptation luminance, in which

subjects viewed the map trials after being adapted to either a very dim or very bright light.

Based on the results, six recommendations are offered for future map design. One, when possible, map symbology should be surrounded by an occlusion zone rather than "inset" into the map. Two, BLACK and MAGENTA symbology should not be used. Three, the absolute luminances of the various map symbols should be kept high, both to enhance luminance contrast against the map background as well as to facilitate recovery from adaptation. Four, full-color map background should generally be used, as the present study showed little evidence for any legibility gains resulting from the "color declutter" feature of the luminance-shaded monochrome-grey condition. Five, the legibility of low-to-moderate luminance symbols will be enhanced if more of their constituent pixels in the matrix are lit. Six, narrow contour interval settings should be avoided, as high contour line density can seriously degrade the legibility of point symbols.

195 Spiker, V. A., Rogers, S. P., & Cicinelli, J. (1986). Selecting colour codes for a computer-generated topographic map based on perception experiments and functional requirements. Ergonomics, 29, 1313-1328.

This paper describes a series of human factors analyses that guided the selection of chromaticities and luminances for a computer-generated topographic map. By virtue of its impressive computational capabilities, the CRT-displayed digital map will greatly facilitate the navigational accuracy and situational awareness of army helicopter aviators during low level and nap-of-the-earth flight. Colour codes were assigned to the digital map's point, linear and area features according to guidelines derived from four colour naming and two symbol search experiments. The design of each study was structured around the map's functional requirements: the five linear feature colours should have high luminance and support absolute colour identification, the three point symbol colours should be identifiable at small sizes; and the four area colours should minimize colour distortions, with the two terrain colours luminance-shaded to depict elevation information. Within these constraints, the results of the colour naming studies yielded an initial set of map colour codes by identifying the most frequently occurring colour confusions arising from the perceptual distortions of brightness contrast, colour contrast and Gaussian spread. The symbol search studies further refined colour selection by identifying the specific foreground background colour combinations that hinder search and by quantifying the conditions under which a colour or monochrome map facilitates symbol search.

196 Steedman, W. C., & Baker, C. A. (1960). Target size and visual recognition. Human Factors, 2, 120-127.

This study was conducted to determine the speed and accuracy of form recognition as a function of the size of target forms for various amounts of detail resolution. The stimulus forms were generated by filling in, on a statistical basis, some of the cells of a 90,000-cell matrix. The subjects were shown a

"briefing target" and instructed to locate that target on a display containing numerous other forms. The significant finding is that both search time and errors remain invariant until the visual angle subtense of the targets falls below 12 min; at values below 12 min performance deteriorates. This effect is independent of the range of resolutions investigated. The implications of these findings to equipment design are discussed.

(From <u>Human Factors</u>, 1960, <u>2</u>, pp. 120-127. Copyright 1960 by the Human Factors Society, Inc. Reprinted by permission.)

197 Sternberg, S. (1967). Two operations in character recognition: Some evidence from reaction-time measurements. <u>Perception & Psychophysics</u>, <u>2</u>, 45-53.

Theories of the recognition of a visual character may be divided into three sets, defined by the way in which the stimulus is encoded before being compared to a memorized target character. A character-classification experiment was performed in which the test stimuli were characters that were either intact or degraded by a superimposed pattern. Analyses of reaction-times in the experiment lead to the rejection of two of the three sets of theories. There appear to be at least two separate operations in the recognition or classification of a character. The first encodes the visual stimulus as an abstracted representation of its physical properties. The second, which may occur more than once, compares such a stimulus representation to a memory representation, producing either a match or a mismatch. A theory of high-speed exhaustive scanning in memory underlies the experiment and is given new support. The method of reaction-time analysis that is introduced, an elaboration of the Helmholtz-Donders subtraction method, may be applicable to the general problem of the invariance of perceived form under certain transformations of the stimulus.

(From <u>Perception & Psychophysics</u>, 1967, <u>2</u>, pp. 45-53. Reprinted by permission of Psychonomic Society, Inc.)

198 Stockman, G. (1978). <u>Toward automatic extraction of cartographic features</u> (ETL-0153). Fort Belvoir, VA: U.S. Army Engineer Topographic Laboratories. (DTIC No. AD-A059 942)

The problem of automatically extracting map symbology from source imagery is studied. It is concluded that a great deal of geographic knowledge used by humans, who currently perform this extraction function, must be made available to machines before the function can be automated. Several geographic knowledge sources are discussed and an attempt is made to define paradigms under which knowledge can be encoded and used in the computer.

An automatic cartographic feature extraction system (ACES) is sketched which represents a best framework for continuing development on this difficult problem given current achievements. A systems approach is taken with first consideration given to desired outputs and available inputs. It is concluded that input/output

technology is far in advance of technology available for interpretation of the data. Emphasis is placed on the use of knowledge by ACES during automatic interpretation of imagery. Many types of knowledge typically used by humans appear difficult to engineer into automatic processes. Use of positional knowledge encoded in a geographic data base (GDB) is selected as the most promising avenue. Proposals are given for future research work in that direction.

199 Teichner, W. H., Reilly, R., & Sadler, E. (1961). Effects of density on identification and discrimination in visual symbol perception. Journal of Experimental Psychology, 61, 494-500.

Twenty-four *S*s viewed a series of 200 slides presented with a 1-sec. exposure. The slides varied in number of different letters (categories) contained and density of the categories. All slides varied randomly in letter location. Half of the *S*s identified the categories; half of them reported the number of categories displayed. The series of slides was presented in random sequence and two variations of grouped density. For the experimental conditions used, the following conclusions appear warranted:

1. For identification of categories, percentage correct identification is inversely proportional to number of categories; percentage of ommissions is directly proportional to number of categories; percentage of commissions is a negatively accelerated decreasing function of categories reaching zero by five or six categories.

2. The maximum number of categories that can be identified in this situation without error is represented by not more than 1 or 2 bits of stimulus information.

3. Neither presentation method nor density affected identification or discrimination except that for the discrimination task, densities greater than one impaired performance.

4. A distinction must be made between information processed as identified categories and as discriminated categories or between perceptual capacity and short term memory capacity. The results indicate that perceptual capacity is the greater of the two.

200 Torre, J. P., & Sanders, L. A. (1958). An investigation of symbol meaning combinations for use in radar displays (Technical Memorandum 1-58). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory. (DTIC No. AD-200 844)

This report covers the attempts to derive a set of symbol forms which could be used to designate "enemy", "friendly" and "unknown" targets on a radar scope. A total of 200 enlisted men were individually tested in two experiments.

A free association type technique was utilized in Experiment I, whereby subjects were required to draw a symbol for each of the three meanings, "enemy", "friendly" and "unknown".

The second experiment was conducted to ascertain the three most representative symbols from those which occurred most frequently in Experiment I.

Specific symbols were obtained along with particular form characteristics for each of the three meanings investigated.

201 Townsend, J. T. (1971). A note on the identifiability of parallel and serial processes. Perception & Psychophysics, 10, 161-163.

Due to significant research effort devoted to discovering whether certain psychological processes are serial or parallel, it seems important to establish the degree to which such processes are identifiable and to investigate possible ways in which such knowledge can improve our experiments. General definitions of parallel and serial systems are given, followed by a qualitative summary of identifiability results obtained with special classes of exponential systems. Some of these results are applied to a current experimental paradigm, and possible techniques are suggested to provide stronger serial-parallel tests and acquire more temporal processing information. Finally, the possibility of S's possessing the ability to manipulate his distribution of processing energy is reacknowledged.

(From Perception & Psychophysics, 1971, 10, pp. 161-163. Reprinted by permission of Psychonomic Society, Inc.)

202 Tversky, A. (1977). Features of similarity. Psychological Review, 84, 327-352.

The metric and dimensional assumptions that underlie the geometric representation of similarity are questioned on both theoretical and empirical grounds. A new set-theoretical approach to similarity is developed in which objects are represented as collections of features, and similarity is described as a feature-matching process. Specifically, a set of qualitative assumptions is shown to imply the contrast model, which expresses the similarity between objects as a linear combination of the measures of their common and distinctive features. Several predictions of the contrast model are tested in studies of similarity with both semantic and perceptual stimuli. The model is used to uncover, analyze, and explain a variety of empirical phenomena such as the role of common and distinctive features, the relations between judgments of similarity and difference, the presence of asymmetric similarities, and the effects of context on judgments of similarity. The contrast model generalizes standard representations of similarity data in terms of clusters and trees. It is also used to analyze the relations of prototypicality and family resemblance.

203 Vicino, F. L., Andrews, R. S., & Ringel, S. (1965). Conspicuity coding of updated symbolic information (PRO-TRN-152). Washington, DC: U.S. Army Personnel Research Office. (DTIC No. AD-616 600)

Forty-eight subjects were presented successive pairs of slides. The first slide contained 12, 18, or 24 flag symbols randomly positioned on a map. The second slide was identical to the first except that 2, 4, or 6 symbols had been added, removed, or repositioned. While viewing the second slide, subjects engaged in information extraction--counting and identifying. After the second slide had been removed, subjects were given an information assimilation task in which they indicated on a scaled-down replica of the first slide the updates they had noted in the second slide. Performance using three different techniques for making updates conspicuous (hard-copy, single-cue, and double-cue coding) was compared with unaided performance (no coding) for each task. The enhancement techniques tried out were relatively simple methods and did not include color coding.

1. In general, increasing either the amount of information presented or the amount of updating resulted in degraded extraction and assimilation performance. In the assimilation task, however, double-cue coding completely prevented the degrading effect of increased amount of information.

2. Double-cue coding improved extraction 97% and assimilation 57% over unaided performance. Single-cue coding improved extraction 68%, assimilation 47%. Hard copy history failed to improve extraction and improved assimilation only slightly, chiefly when repositioned updates were presented.

3. Performance in both extraction and assimilation was best on slides from which symbols had been removed, poorest on slides in which symbols had been repositioned.

4. As extent of change increased, errors of omission increased more rapidly than errors of commission.

204 Vicino, F. L., & Ringel, S. (1966). Decision making with updated graphic vs alpha-numeric information (PRO-TRN-178). Washington, DC: U.S. Army Personnel Research Office. (DTIC No. AD-647 623)

To keep pace with technological advancements in military operations and to meet the need of commanders to make tactical decisions consistent with rapid changes of events, the Army is developing automated systems for receipt, storage, retrieval, and display of different types and vast amounts of military data. As part of the requirements for research, studies have been conducted by the COMMAND SYSTEMS Task bearing upon facilitation of decision making and information assimilation from displays. The present study is concerned with the effects of alpha-numeric and graphic presentation of information on the accuracy and timeliness of decision making and confidence in the decision made. These variables were examined in the context of a simulated constantly changing battlefield situation. A series of slides depicting battlefield information were presented both alpha-numerically and graphically to subjects. Each subject was asked to make a decision as to the enemy forces activity and to express his confidence in his decision in terms of probability odds. Also, for each mode of display, the sequence of information was presented at two different rates of

updating -- 7 vs 14 updated slides. No differences were found between alphanumeric and graphic presentation in terms of quality or timeliness of decision or in confidence score; nor were they found in results with the two rates of updating. Greater shifts in level of confidence were shown, for both modes of presentation, from slide to slide in the 7-slide updating than in the 14-slide updating. Results also showed that, on the average, subjects whose final decision was correct had made the correct response three-fourths of the way to their final decision.

Findings encountered suggest further research is needed for information on rate of updating limits and on factors and work methods which increase confidence in decision along with quality of decision.

205 Wheatley, E. (1977). An experiment on coding preferences for display symbols. Ergonomics, 20, 543-552.

In an experiment to investigate use of multidimensional coding for displays, subjects were shown a series of pairs of small hexagonal figures, and were asked to choose the more 'hostile' of each pair. They were instructed that for each symbol hostility was shown by spikiness (shape), higher numerals, and increased redness. For most of the pairs there were no correct answers, since according to a straight-forward additive model the symbols within each pair had equal values of hostility. Subjects were unaware of this, and it is postulated that they chose on the basis of the stimulus feature that seemed most salient to them. Results of the experiment indicated that spikiness and colour had a much greater saliency than the numerals.

Subjects' ability to combine evidence from differently coded sources was investigated with other pairs of symbols for which there were right and wrong answers. Analysis of errors confirmed the saliency findings, and suggested that three different 'dimensions' may be the most that should be used for coding.

206 Williams, A., & Weisstein, N. (1978). Line segments are perceived better in coherent context than alone: An object-line effect in visual perception. Memory & Cognition, 6, 85-90.

In a series of four experiments, observers identified a briefly flashed line segment more accurately when it was part of a drawing that looked unitary and three-dimensional than when the line segment was presented alone. This extends earlier findings of better identification of a line segment when it is part of an apparently unitary, three-dimensional drawing than when it is in a less coherent flat design; and these results demonstrate a visual effect analogous to the word-letter effect which uses nonlinguistic materials. Experiment 1 demonstrates the existence of the object-line effect and shows that it does not depend on the presence of a subsequent mask; Experiment 2 shows that the effect holds up with two-alternative forced-choice presentation; Experiment 3 demonstrates that the

effect is not due to bright endpoints which may occur when the target line appears with a context; and Experiment 4 shows that the effect is as strong when the target line segments occupy widely separated spatial locations as it is when they occupy nearby, potentially confusable locations.

(From Memory & Cognition, 1978, 6, pp. 85-90. Reprinted by permission of Psychonomic Society, Inc.)

207 Williams, E., & Teichner, W. H. (1979). Discriminability of symbols for tactical information displays (NMSU-AFOSR-TR-79-1). Las Cruces: New Mexico State University, Department of Psychology. (DTIC No. AD-A070 989)

The relative discriminability of 210 stimulus items was determined by a comparison of response time and errors in a search task in which the operator identified symbols as examples or non-examples of a prespecified target item. The characteristics of the target item relative to non-target items determined the response times to target and non-target items and the variability among non-target response times. Non-targets which were highly confusable with the target tended to increase response time and variance. Symbols were ranked according to target and non-target response times.

208 Williams, J. R., & Falzon, R. P. (1963). Comparisons of search time and accuracy among selected outlined geometric symbols with various overlays. Journal of Engineering Psychology, 2, 112-118.

Since recognizability of certain combined-type symbols (solid geometric combinations) proved inadequate in a previous experiment performed by the authors, a second experiment was designed to test a new set of 25 (outlined) combined-type symbols. The results were analyzed by a confusion matrix and a comparison between search time and accuracy data. On the basis of these results, it was concluded that certain outlined symbols, when combined with various lines (diagonals, horizontals, verticals), could be used in complex displays.

In a previous study, the authors (Williams and Falzon, 1963) found that various combinations of solid geometric type symbols did not prove to be distinguishable enough for use in a complex Air Force information system. Since only a limited number of symbol positions were available in the system's display generator and symbols could be overlaid within the equipment, it was highly desirable to obtain a set of symbols which could be combined and still be accurately recognized. Results found in the first experiment indicated that outlined-type symbols (outlined squares, circles, etc.) were recognized with more accuracy than solid-type symbols (solid squares, circles, etc.). The purpose of this experiment was to test a list of outlined symbols, combined with various lines (diagonals, horizontals, etc.), in order to obtain a set of combinable symbols which could be used with confidence in system displays.

209 Williams, J. R., & Falzon, R. P. (1963). Relationship of display system variables to symbol recognition and search time. Journal of Engineering Psychology, 2, 97-111.

In order to investigate variables involving symbol recognition as related to complex display systems, 100 symbols were presented singly on a screen for .5 seconds, and subjects identified the "just seen" symbol on a 10 x 10 printed matrix. The experiment was run under the following conditions: 2 types of matrices, 3 viewing angles, 2 form dimensions, and 3 form classes. Two 2x3x2x3 analyses of variance models (accuracy and search time) indicated that the type of matrix was not significant for either criteria, viewing angle was significant for accuracy, the form class was significant for both criteria, and the form dimension was significant only for search time. A confusion matrix was constructed from the recognition data to determine which symbols were mistaken for others. On the basis of the results, recommendations are made on symbol selection for complex displays.

210 Wong, K. W., & Yacoumelos, N. G. (1973). Identification of cartographic symbols from TV displays. Human Factors, 15, 21-31.

An experiment was conducted to investigate the resolution capability of TV displays in distinguishing details from line-maps and picto-maps, and to establish the relative merits of color and black-and-white TV display systems. The experimental variables included two display types, three map types, four symbol types, and three image-resolution levels. The results showed that a color display offered some advantage over a black-and-white display of equivalent effective resolution. However, a black-and-white system could provide the same performance at the expense of a slightly higher effective resolution. At an image-resolution level of nine TV-lines/mm, alphanumeric symbols were identified almost 100% correctly for all map types and display types. Area and line symbols achieved their maximum level of performance at five and seven TV-lines/mm, respectively. United States Geological Survey (USGS) 1:24,000 maps were significantly better than TOPOCOM line-maps and picto-maps.

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(002) (029) (030) (050) (051) (068) (097) (098) (113) (147) (163) (177) (183)

Association

(020) (029) (030) (036) (037) (040) (047) (050) (051) (063) (068) (069) (072) (097) (098) (099) (106) (113) (115) (118) (119) (125) (128) (129) (133) (141) (142) (143) (147) (151) (163) (167) (183) (200)

Compatibility

(006) (007) (008) (026) (030) (040) (047) (050) (051) (063) (069) (097) (098) (106) (113) (116) (118) (119) (125) (128) (133) (147) (183) (200)

Detection

(001) (005) (015) (016) (017) (022) (023) (025) (026) (081) (085) (086) (089) (091) (093) (095) (104) (112) (113) (114) (143) (147) (180) (183)

Discrimination

(011) (012) (013) (018) (019) (021) (023) (024) (025) (027) (030) (039) (041) (042) (043) (044) (045) (049) (050) (051) (053) (054) (055) (057) (058) (059) (060) (061) (062) (064) (065) (070) (071) (072) (073) (079) (083) (087) (088) (089) (090) (092) (094) (095) (097) (098) (100) (101) (102) (103) (105) (107) (108) (109) (111) (112) (113) (116) (119) (121) (122) (123) (124) (125) (127) (135) (137) (143) (145) (146) (147) (148) (149) (150) (152) (154) (155) (156) (157) (161) (162) (164) (165) (166) (167) (168) (169) (171) (177) (178) (179) (180) (181) (182) (183) (185) (187) (192) (194) (198) (199) (202) (205)

Identification

(001) (003) (005) (006) (007) (009) (010) (011) (012) (013) (015) (016) (021) (024) (029) (030) (031) (032) (033) (036) (037) (041) (042) (043) (045) (049) (050) (051) (052) (054) (055) (056) (057) (058) (059) (060) (061) (067) (069) (073) (082) (089) (092) (094) (095) (097) (098) (099) (104) (106) (107) (109) (111) (112) (113) (115) (116) (117) (118) (119) (121) (122) (124) (125) (127) (132) (136) (141) (142) (143) (144) (145) (146) (147) (148) (150) (152) (154) (155) (156) (157) (158) (160) (161) (162) (163) (167) (168) (169) (170) (177) (178) (179) (180) (181) (182) (183) (185) (190) (192) (195) (198) (199) (201) (203) (206) (210)

Opinion/Rating

(001) (010) (017) (058) (059) (060) (061) (063) (088) (097) (098) (101) (104) (106) (110) (111) (113) (115) (124) (129) (133) (134) (138) (139) (140) (144) (147) (154) (163) (175) (183) (186) (204)

Recognition

(014) (017) (018) (019) (024) (025) (026) (027) (028) (029) (031) (032) (033) (035) (039) (044) (048) (051) (057) (062) (068) (084) (089) (109) (113) (114) (115) (123) (126) (147) (164) (165) (166) (172) (180) (196) (197) (198) (208) (209)

Scenario

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Search

(001) (010) (014) (015) (016) (017) (025) (034) (035) (038) (045) (051) (059) (060) (061) (066) (067) (068) (070) (071) (074) (075) (076) (077) (078) (080) (082) (088) (089) (096) (100) (104) (109) (112) (113) (120) (121) (122) (130) (147) (159) (160) (173) (174) (176) (178) (180) (183) (184) (188) (189) (191) (193) (194) (195) (203) (207) (208) (209)

Tracking

(001) (015) (016) (087) (123) (147) (150) (158) (181) (182) (203)

PROCESSING

Cognitive

Depth/Level

(006) (007) (008) (009) (010) (011) (013) (014) (015) (016) (020) (023) (030) (041) (044) (045) (049) (050) (051) (057) (058) (059) (060) (061) (097) (098) (104) (107) (109) (113) (115) (118) (119) (124) (125) (126) (133) (136) (137) (142) (148) (150) (151) (154) (155) (158) (163) (167) (170) (173) (175) (177) (178) (179) (180) (181) (182) (183) (188) (199) (200) (202) (203) (206)

Global/Local

(026) (031) (032) (033) (036) (037) (066) (067) (075) (076) (077) (078) (082) (088) (096) (099) (112) (114) (117) (121) (130) (146) (149) (156) (157) (160) (164) (165) (168) (169) (171) (180) (183) (184) (185) (190) (191) (193) (194) (197) (207) (208) (209)

Serial/Parallel

(003) (018) (019) (031) (032) (034) (038) (052) (064) (065) (070) (071) (072) (073) (075) (076) (077) (078) (079) (080) (096) (105) (112) (122) (123) (132) (143) (152) (159) (174) (183) (201)

Gestalt

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Psychophysical

(005) (012) (013) (017) (021) (022) (025) (027) (028) (039) (042) (045) (048) (053) (054) (055) (062) (074) (081) (083) (084) (085) (086) (087) (089) (090) (091) (092) (093) (095) (100) (101) (102) (103) (108) (111) (113) (116) (120) (126) (127) (135) (140) (143) (145) (183) (189) (192) (195) (196)

Transmission

(004) (006) (007) (008) (009) (127) (135) (199)

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